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Wildlife Management Implications of Petroleum Exploration and Development in Wildland Environments

Marianne Bromley

THE AUTHOR

MARIANNE BROMLEY earned a B.S. degree in fisheries and wildlife biology from Iowa State University and an M.S. in resource geography from Oregon State University. She has participated in research on Canada geese, arctic water birds, bald eagles, and coots in Alaska, Oregon, and South Carolina. This report, based on her master's thesis, was conducted cooperatively with the Intermountain Research Station, USDA Forest Service. She is presently involved in wildlife research and writing in Canada's Northwest Territories, located at Yellowknife.

RESEARCH SUMMARY

This report describes the sequence of events, their characteristics, and the associated environmental disruptions involved in the exploration, development, and production of petroleum. The potential effects of environmental disruptions on wildlife behavior, populations, and habitat are evaluated, drawing on a review of the literature, supported by a selective, annotated bibliography. Potential effects are numerous and varied. Impact severity is site specific and depends on the sensitivity of the species affected, the nature of the environmental disruption, habitat characteristics, and the availability and condition of alternative habitat. The major wildlife groups affected by petroleum activities are ungulates, carnivores, water birds, upland birds, and raptors. Possible approaches to minimizing adverse effects on wildlife are presented, including changes in management of petroleum projects, personnel, and wildlife habitat and populations.

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Cover: Antelope in front of oil well.

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INTRODUCTION

The current domestic energy policy of becoming as self-sufficient as possible is encouraging rapid increases in petroleum exploration and development. Public lands are receiving much attention as "our last unexplored frontier for oil and gas" (Dibble and Hamilton 1979). There is pressure to reevaluate laws, regulations, and policy directives that restrict exploration and development on many Federal lands, including existing and proposed Wilderness Areas, RARE II lands, critical wildlife habitats, and other undeveloped wildlands (American Petroleum Institute 1981; Rogers 1981; Schumacher and others 1979). Oil and gas leases were applied for on more than three dozen Wilderness Areas before the terms of the Wilderness Act ended leasing in 1984. Approval of leases has been recommended for several Wilderness Areas in the West (Nice 1982). Considerable conflict is occurring between oil and environmental interests in the Rocky Mountain Overthrust Belt, a geological formation believed to have great oil and gas potential, but underlying much of the wildlands in Wyoming, Idaho, Utah, and Montana (Hamilton 1978; Kline 1981; Whipple 1977).

The rapid rate of resource development dictates that resource managers become familiar with the potential problems inherent in energy development and begin to implement guidelines to minimize adverse effects on the wildland environment (Burger and Swensen 1977). One of the major problems associated with energy development concerns the potential effect of petroleum development activities on wildlife, especially those species dependent on a wildland environment. Construction of roads, drilling pads, and pipelines, the influx of people and machinery, and the development of construction camps and boom towns are but a few of the activities that create disruptions potentially threatening to wildlife not habituated to high levels, or the presence, of human activities.

Managers faced with the task of protecting wildlife in such a situation are handicapped by the lack of readily available information on the responses of wildlife to various development activities. Although research into the effects of disturbances specific to the petroleum industry is limited, numerous studies have been completed describing the effects of other human activities that may result in environmental disruptions (noise, increased traffic) similar to those caused by petroleum exploration and development operations. Results of this work, however, are dispersed in the scientific literature. This report was prepared with the belief that a review and synthesis of this research would be useful to managers, especially while awaiting results from studies dealing more specifically with the effects of petroleum development on wildlife.

Purpose and Objectives

The purpose of this report is to provide resource managers with a compilation of background information useful in the development of guidelines and/or management strategies designed to minimize adverse effects of petroleum exploration and development on wildlife in wildland environments. It is not intended for use in deciding whether or not to allow development, but rather to aid in the identification of wildlife/land use conflicts, to increase the manager's awareness of the implications of development, and to provide information that may facilitate minimization of harmful effects in the event that development in sensitive areas is approved. It does not consider the esthetic problems that may be associated with development of wildland areas. The major objectives of the report are:

1. To familiarize resource managers with the sequence of events, major activities, and associated environmental disruptions involved in the exploration, development, and production of petroleum.
2. To provide an overview and evaluation of the potential effects of these disruptions on wildlife behavior, habitat, and populations by presenting an annotated bibliography of literature on effects of land use activities.
3. To present a general description of possible approaches to minimizing these effects (mitigation, management strategies).

For the purpose of this paper, "environmental disruption" is defined as a human-caused modification of the environment that may ultimately result in adverse effects on wildlife. It includes changes of a physical nature, and changes in the level or type of activities in an area. A disruption results from one or several development activities and represents the mechanism through which wildlife is affected. It is considered here to be a common denominator allowing comparison between the effects of various land use activities and potential effects of petroleum extraction activities.

Scope

Petroleum development activities may result in a wide range of effects on the physical environment—soil, vegetation, water, air—but these are addressed here only as they directly relate to terrestrial wildlife. The subjects of oil spills, pollution, and major effects on aquatic habitats, although potentially serious, are addressed only in a very general way because such information would easily fill a separate paper. The range of species discussed was determined by the available literature and includes primarily ungulates, carnivores, raptors, and waterfowl. Songbirds, shorebirds, and furbearers are addressed more briefly. Discussion of fish and other aquatic organisms is beyond the scope of this report.

Because of its broad geographic coverage the report may be used in many areas. The majority of published research to date has been conducted in the Arctic, and more recently in the Rocky Mountains and several north-central and eastern States. Results of arctic studies constitute a large part of this paper, but are reported only when relevant to other geographic areas. Discussion of problems specific to arctic development—such as the need to import all equipment and workers, the special requirements of permafrost construction, and the vulnerability and low productivity of northern biological systems—is of interest to a relatively limited audience and has already received good coverage in other publications (Hanley and others 1980; Klein 1973; USGS 1979). It is therefore not repeated here.

This paper is based on a review of literature published in scientific journals, magazines, government publications, private industry reports, and a few unpublished papers. It represents a synthesis of data covering a wide variety of wildlife species, geographical locations, and land uses. Legitimate concerns exist over (1) the validity of generalizing or extrapolating from one situation or species to another, and (2) the validity and practicality of using behavioral responses as measures of effect, as they have not been demonstrated to relate directly to changes in productivity or survival of a population (Jingfors and Gunn 1981). Without specific project descriptions and complementary species studies, however, managers must mainly rely on general findings from past studies and general wildlife observations when dealing with immediate problems and develop measures to minimize effects of current development on wildlife. The present rate of development precludes the possibility of long-term, species- and site-specific research that might relate individual and population responses and provide more definitive conclusions concerning the effects on wildlife. Many authors cited in this paper specify that results apply only to circumstances under which the study was conducted, and request that caution be used in making generalizations from their research.

Specific information presented in this paper is intended as background data to supplement local inventory and research data. Resource managers will need to make judgments, based on professional expertise and awareness of the limitations described, in extrapolating from results reported in this paper to their particular situations. Managers should be aware that new research on the effects of development on wildlife is continually being completed, and they should be ready to alter management actions, if necessary, as future research results become available.

Much of the published research on wildlife-petroleum relations has been conducted in the arctic. Here, caribou graze near an oil derrick.

EXPLORATION AND DEVELOPMENT ACTIVITIES

This section describes the general sequence of operations and types of activities involved in petroleum exploration, development, and production. The degree and nature of development activity is site-specific to each well or oil field, and depends on such factors as geology and reservoir characteristics, terrain conditions, and existing access and support facilities. Although environmental disruptions are common to all phases of development, their magnitude may vary and is also strongly dependent on site-specific conditions (Hanley and others 1980). Nonetheless, general oil field practices can be outlined. The sequence of operations normally progresses through five phases: (1) preliminary exploration, (2) exploratory drilling, (3) development, (4) production, and (5) reclamation/abandonment.

Table 1 summarizes activities involved during each phase of operation. Table 2 shows the environmental disruptions resulting from each of these activities. The major sources used throughout the following sections describing oil field operations are Amerada Hess Corp. 1980; Hanley and others 1980; Overthrust Industrial Association 1981a; USDA 1981a, 1981b; USDI 1979, 1981a, 1981b. Additional references are cited as necessary.

Table 1.—Phases of petroleum development and activities occurring during each phase

Activity	Development phase				
	Explore	Drill	Develop	Produce	Abandon
Ground surveys	x				
Seismic trail clearing	x				
Seismic wave production/recording	x				
Clearing/grading right-of-way		x	x		
Road construction	x	x	x	x	
Mobilization of trucks/equipment	x	x	x	x	x
Site development (clearing/grading)		x	x	x	
Drill pad construction		x	x		
Excavation of storage/mud pits		x	x		
Drilling and related activities		x	x		
Water supply		x	x		
Borrow pit excavation		x	x		
Wellhead/pump unit installation			x		
Construction of process/treatment/ storage facilities				x	
Installation of flow lines				x	
Erection of power lines				x	
Communication system development				x	
Operation of process/treatment facilities				x	
Pipe stringing				x	
Trenching and pipe installation				x	
Pipe burial and backfill				x	
Maintenance and inspection				x	x
Accidents		x	x	x	x
Secondary recovery				x	
Air support	x	x	x	x	x
Worker accommodations		x	x	x	x
Increase in local population		x	x	x	
Development of ancillary industry				x	
Well plugging					x
Site restoration/revegetation					x

Table 2.—Potential environmental disruptions resulting from oil field activities

Activity	Potential environmental disruption						
	Noise	Aircraft	Human intrusion	Traffic and access	Structures and facilities	Alteration of vegetation/ land	Harmful substances
Ground surveys			x	x			
Seismic trail clearing	x		x	x		x	
Seismic wave production/ recording	x		x				
Clearing/grading right-of-way	x		x	x		x	
Road construction	x		x	x	x	x	
Mobilization of trucks/ equipment	x			x			x
Site development (clearing/grading)	x		x			x	
Drill pad construction	x		x			x	
Excavation of storage/mud pits	x		x		x	x	x
Drilling and related activities	x		x				
Water supply	x		x	x	x		
Borrow pit excavation	x		x			x	
Wellhead/pump unit installation	x				x		
Construction of process/ treatment/storage facilities	x		x		x	x	
Installation of flow lines	x				x	x	
Erection of power lines	x				x	x	
Communication system development	x				x	x	
Operation of process/ treatment facilities	x		x				
Pipe stringing	x		x		x		
Trenching and pipe installation	x		x			x	
Pipe burial and backfill	x		x		x	x	
Maintenance and inspection			x				
Accidents						x	x
Secondary recovery	x		x				
Air support	x	x					
Worker accommodations			x				
Increase in local population			x	x			
Development of ancillary industry			x			x	
Well plugging	x		x				
Site restoration/revegetation	x		x				

Preliminary Exploration

The main purpose of this phase is to locate and obtain detailed information on geologic structures with the potential for producing oil and gas. It can be conducted on leased or unleased lands. Initially, geologic literature, surface maps, aerial photos, low-altitude reconnaissance flights, and higher altitude magnetic and gravity survey flights are used to search for the presence of structures that may contain oil and gas traps or reservoirs. More detailed ground surveys, and sampling of surface and subsurface rocks, follow at promising sites. Environmental disruptions through this stage are minimal, although small crews with light vehicles must be present and some off-road travel may be necessary in areas without existing access roads or trails.

If these surveys continue to indicate the probable occurrence of petroleum accumulations at a site, seismic prospecting normally ensues. This procedure involves the artificial generation of shock waves and the subsequent recording, by special detectors, of the times necessary for the waves to be reflected back to the surface from rock interfaces at various depths. The results indicate the depths of specific formations. The energy source and sensors are located along straight seismic lines laid out in a grid.

Two general types of seismic operations are possible, their uses determined by the difficulty of access and the sensitivity of the environment:

1. Operations that use heavy, truck-mounted equipment for drilling shot-holes, recording, and in some cases generating seismic waves. Shock waves may be produced by several methods:

— explosives loaded into 50- to 200-ft drilled holes and detonated.

— "thumper" trucks drop a heavy weight to the ground several times in succession along a predetermined line.

— truck-mounted vibrator pads that vibrate the earth at intervals along a line.

A typical operation may use 10 to 15 people and five to seven trucks. If access is inadequate, a network of temporary roads and trails may have to be constructed. The amount of preparation necessary depends on types of vegetation and ruggedness of terrain. Roads are aligned in straight lines regardless of gradient or terrain. Trails may have to be cut through forested areas. These operations may result in various disruptions of the environment, including disturbance of vegetation and ground surface, blasting and other noise, and increased presence of humans and vehicles associated with the exploration activity, or local residents taking advantage of the increased access.

2. Portable operations transported by helicopter. Employees and equipment are flown in from staging areas. Explosives are detonated in shallow holes on the surface of the ground or on stakes or platforms. Vegetation and surface disturbance are reduced because road construction is not required. Nevertheless, helicopter activity will result in increased noise.

The degree of impact of seismic activity depends on its intensity—the number of concurrent programs, the number and spacing of lines, and the length of time spent in critical habitats. Two aspects must be considered: the immediate effect of the actual exploration activity, and the subsequent effects resulting from increased access (Stubbs and Markham 1979).

Certain characteristics specific to seismic operations may intensify effects on wildlife. Crews are constantly moving and follow a course unpredictable to wildlife. The activity may cover a large area, and is not confined to one site as is characteristic of drilling operations. Blasting noise is sudden and unpredictable, and its effect may extend beyond the area of immediate surface disturbance and activity. Exploration activities may be especially disruptive if poorly planned and subcontracted to small companies with restricted budgets. Such firms may be less concerned than large oil companies with public relations and therefore more likely to take environmentally destructive shortcuts (Klein 1973).

Exploratory Drilling

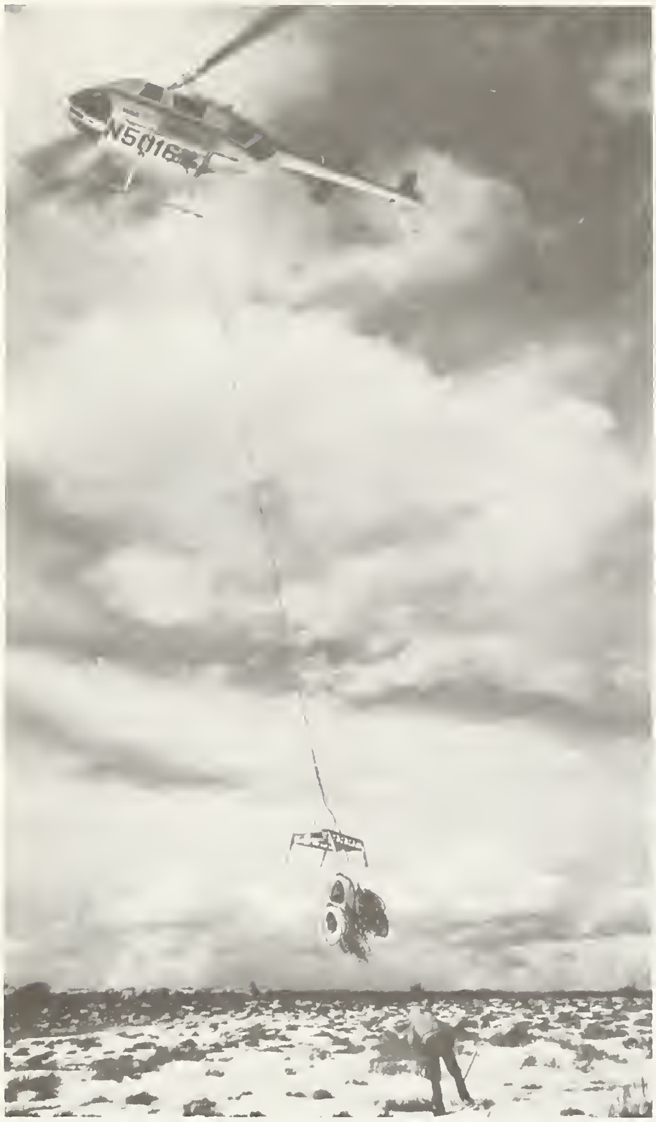
In cases where preliminary explorations still indicate the possible occurrence of oil, drilling of an exploratory or "wildcat" well may be initiated to determine if oil and/or gas of commercial quantity and quality exist. Drilling does not begin until a lease has been acquired by the operator. Well depth depends on the geology of the area. Wells in the Overthrust Belt are commonly drilled to depths up to 18,000 ft (Overthrust Industrial Association 1981b), and completion may take 6 months. In other areas, shallower wells of a few thousand feet are common and may be completed in a few weeks.

The steps undertaken in exploratory drilling operations are:

1. **Construction of temporary access roads able to accommodate continuous traffic of large, heavy trucks hauling the drill rig and other materials and equipment to and from the drill site.**—Factors such as time of year, terrain, and duration of drilling activity may influence road construction requirements. Standard road construction practices are followed. Heavy earth-moving equipment is used to clear vegetation for a 10- to 18-ft wide running surface, grade the road surface, cut and fill slopes, cut ditches and borrow pits, transport material used to crown the running surface, install culverts, etc.

2. **Preparation of well site.**—This requires clearing and leveling an area of 1 to 7 acres (10 acres for deep wells) for the drill pad (Kline 1981). This pad holds the drilling rig, mud pumps, mud pits, generators, pipe rack, and tool house. Construction requires stripping of topsoil; cutting, filling, and grading to construct a flat drilling pad; and excavating and banking mud pits to hold drilling mud, cuttings, and waste fluids. The rig is erected and other equipment is hauled in and stored on the pad awaiting use.

3. **Provision of adequate water supply (50,000 to 100,000 gal/day).**—Water may be trucked to the site, or transported by a surface pipeline laid to a water source nearby.



Some seismic exploration for petroleum deposits is conducted using helicopter access rather than trucks, with different types of wildlife effects.

4. **Drilling.**—The actual drilling operation normally uses a rotary drill bit and drill string, consisting of long lengths of pipe, which are rotated and gradually bore into the earth. Additional strings of pipe, or casing, are cemented inside the hole, primarily for safety reasons. Drilling mud, generally a mixture of water, clay, and chemical additives, is forced under pressure down the drill pipe to cool and clean the bit and carry cuttings to the surface. Large, loud, diesel power plants are often required for power at the drilling site (Longley and others 1978).

Various tests, such as "logging," measure the physical characteristics of the rock formations and associated fluids. The well will be completed if sufficient quantities of oil and/or gas are indicated. Completion requires installation and cementing of casing to the bottom of the hole. If no oil or gas is encountered, the well is usually abandoned. If the well is a producer, the area is developed.

Exploratory drilling tends to be much more disruptive to the environment than are seismic operations. This is primarily due to the increased access and need for construction, and the consequent increase in human activity, noise from vehicles and machinery, and disturbance of vegetation and ground surface.

Crews work around the clock (three shifts of five to eight workers) and service traffic may be continuous. Although much of this activity is concentrated in the area of the drill pad and roads, noise associated with construction machinery, heavy trucks, and drilling may be persistent and extend beyond the area of immediate activity. In addition, construction of new roads may open up, temporarily or permanently, previously inaccessible areas for recreation by local residents and workers. The degree of surface disturbance required for the drill pad, mud pits, and road construction may vary according to such factors as well depth, rig size, mud system efficiency, and terrain. For instance, in the Overthrust Belt, the combination of rough terrain and deep wells commonly results in larger disturbed areas. Toxic substances (fuel, crude oil, chemicals) may be released from accidents or leaks (Longley and others 1978). Site-specific disruptions resulting from a well may last only a few months; however, an exploratory program for an area may include many wells and may last for years.

Development and Production

Because the two phases often occur simultaneously and result in similar environmental disruptions, development and production will be discussed together. If a wildcat well becomes a "discovery well" (a well that yields oil or gas in commercial quantities), development begins. Subsequent wells are drilled to establish the reservoir's limits and to facilitate planning the best pattern of wells to drain the field. The drilling procedure is the same as that followed for exploratory wells. As development wells are drilled, they may be tested and temporarily shut in until means of transporting the oil and/or gas is arranged.

Oil field production begins when the oil or gas can be transported by pipeline or truck. This usually occurs soon after completion of the discovery well and is often concurrent with development operations. Temporary facilities are gradually replaced by permanent ones. Often, the majority of surface disturbances occur in this phase, as new wells are drilled periodically throughout the field and pipelines and operational facilities must be built. The extent of surface facilities is determined by reserve size, reservoir characteristics, the mixture of fluids being produced, transportation strategies, availability of existing infrastructure, and whether or not the field is unitized.[1] Such facilities may consist of any or all of the following:

1. **Drill sites.**—Drilling may continue throughout the producing life of the field. Facilities needed are the same as for exploratory drilling.

[1]Unitization refers to the joining of numerous leases into "unitized" fields which are developed and operated as a unit, upon agreement by developers, without regard for separate ownership.

Oil field development and oil transporation and storage facilities can affect considerable area.

2. **Well heads.**—If formation pressure is sufficient to force the oil to the surface, the well is completed as a free-flowing well and simply closed off using a "Christmas tree," an assembly of valves and pressure regulators used to control the flow of the well. Wells using artificial lift have simple well-head arrangements of valves.

3. **Pumping equipment.**—If natural pressure is not sufficient to raise the oil, a pumping unit may be needed. Surface pumps are usually powered by internal combustion engines or electric motors, which are generally preferred by operators and make less noise but require a source of electricity.

4. **Storage facilities.**—Storage tanks or tank batteries may be placed at well sites or in central locations to be used as collection and shipping points for oil and gas.

5. **Separating and treating facilities.**—If the oil contains gas and water, they are separated, at facilities usually located at the storage tank batteries, before the oil is stored. Gas may be returned to the reservoir or marketed. If marketed, additional treatment facilities may be needed to upgrade the gas for commercial pipeline transport. Deep drilling often produces hydrogen sulfide, a highly toxic and corrosive "sour" gas. The gas must be "sweetened" at plants located near the center of the field because transporting the gas is dangerous. Several plants may be required in an area; and each may cover 20 to several hundred acres (Kline 1981; O'Gara 1980). Separation of water, which often contains very high salt concentrations, may require tall settling tanks or facilities for chemical or heat treatment.

6. **Salt water disposal** systems.—Reinjection of water into the formation may require additional wells and maintenance roads. In some cases, dry holes or depleted wells are used. Surface exploration or percolation pits are sometimes used for salt water disposal or, where necessary, for skimming of oil not completely separated (Clifton and LaVelle 1978; Conner and others 1976).

7. **Roads.**—The design standard of existing roads will be upgraded if necessary for permanent, all-weather access. This may involve widening, ditching, graveling, crowning, or capping the roadbed and installing culverts. Additional roads will need to be constructed to allow increased access to the wells, to treatment and storage facilities, and for construction and maintenance of pipelines, transmission lines, and communication sites.

8. **Electric transmission lines.**—Lines and rights-of-way may be required from main lines to each well site and tank battery and to the communication and production facility. These range from small lines on simple wood poles in narrow rights-of-way to extra-high-voltage lines on steel structures in corridors. Construction usually involves road construction, clearing of vegetation for a right-of-way of variable width, tower installation, and conductor stringing (Lee and Griffith 1978).

9. **Communication systems.**—Communication lines are usually buried, requiring a construction easement and permanent right-of-way. Communication sites typically include repeater and terminal facilities, electric power source, and an access road to permit year-round servicing. All communication facilities have some type of antenna on top of wooden poles or steel towers, which vary in height up to several hundred feet (USDI 1976b).

10. **Pipelines.**—Numerous pipelines will be required. Oil and gas are transferred within the field from the wells to gathering stations, and between gathering stations and treatment facilities, in flow lines generally 4 to 8 inches in diameter. Flow lines can be on the surface, buried, or elevated.

Larger pipelines of variable diameter and length are needed to transport the oil and gas from gathering stations to refineries. The conventional below-grade construction mode typically used for both oil and natural gas pipelines consists of the following major steps (USDI 1976a; USDI and Fed. Energy Reg. Comm. 1981):

— Construction of access roads between right-of-way and pipe yards, borrow pits, and storage areas.

— Preparation of right-of-way. All vegetation and debris must be cleared and the right-of-way graded as necessary. Blasting may be required for removal of rock. Construction requirements, pipe diameter, and soil condition usually establish the width of the right-of-way.

— Excavation of borrow pits as necessary for gravel.

— Pipe mobilization and stringing. The pipe must be hauled to the right-of-way and placed in assembly position along the ditch centerline, with openings at given intervals.

— Installation. The burial trench is dug and the pipe bent, aligned, welded, coated, and lowered into the ditch by crews using various types of equipment. The trench is backfilled with ditch spoil, creating a berm over the pipeline. The right-of-way is then graded to original contours (except berm) and vegetated.

The pipeline is typically laid by several "spreads" working simultaneously along its route. Other components of the pipeline system must also be constructed as necessary, including block valves, metering stations, maintenance bases, cathodic protection stations, and pump and compressor stations to maintain pipeline pressure. Each of these requires a variable surface area ranging from several hundred square feet to several acres and may require additional access.

11. **Facilities for secondary recovery.**—After years of primary production, the reservoir's natural pressure and oil yield declines. Secondary recovery, involving injection of water (water-flooding), gas, or other liquids, is often initiated to artificially increase reservoir pressure.

A service infrastructure is also developed during this phase. A substantial increase in the local population, or "boom town" development, results from the influx of: (1) a very large labor force (hundreds to thousands) required for oil field development activities, (2) workers' families, (3) personnel of service professions needed to provide for the increased population, and (4) personnel of ancillary industries which may result from oil field development. These people require living accommodations, which may consist of (1) company construction camps in remote areas, (2) housing in local communities, or (3) "squatting" with tents, campers, or trailers (Kline 1981). The population increase may last for varying lengths of time, but tends to be greatest during the development and construction phase as temporary workers are imported. A significant increase in permanent residents is likely. In remote areas with difficult access, aircraft support may be needed. This could require construction of airstrips or helipads.

Development and production may take many years and include many wells and facilities. Once a field has been established, environmental disruptions become extensive, cumulative, often long term, and would occur continually in varying degrees because of the need for recurring human activity.

Wildlife habitat alteration or destruction can be considerable due to the increased surface disturbance and vegetation clearing needed for (1) construction activities and (2) placement of permanent operational facilities, well sites, roads, worker accommodations, etc. Aquatic habitats may be altered as a result of siltation and erosion from culvert placement, stream bottom pipeline crossings, and runoff from dirt roads and construction activities.

The presence of human-associated structures and facilities (buildings, roads, pipelines, transmission lines) will increase. Substantial human intrusion into wildlife habitat will result from (1) activities directly related to oil field operations and (2) secondary activities related to the resultant increases in access and population. Traffic will increase significantly. There will be a greater demand on wildlife and its habitat for recreational purposes. Sociological data indicate that energy-development-related workers have a higher demand for outdoor recreation, especially hunting, fishing, and use of recreational vehicles, and therefore a greater potential for increasing impacts on wildlife, than do resident populations in development areas (Streeter and others 1979). Effects from secondary activities may be greater in the long term than those from development itself.

Deliberate harassment of wildlife may occur in some situations. Also, attraction of scavenger species to construction camps, drill sites, or other concentrations of human activity may be a problem in some areas, especially where food, garbage, and sewage are accessible to the animals.

Varying levels of noise will be generated by construction machinery, heavy trucks and other traffic, blasting, generators, air traffic, and other equipment and operations. Noise may be temporary and site-specific, or long-term, depending on the source. Gas turbines and compressor stations are sources of very high level, long-term noise (Banfield 1971; USDI and Fed. Energy Reg. Comm. 1981).

Accidents causing spills and leaks of toxic or otherwise environmentally damaging substances can be expected, despite precautions taken to prevent them. Liquid spills (fuel, oil, brine, chemicals) occur along pipelines, from mud pit failure, at storage tanks and well heads. In some areas, brine spills are a more serious problem than oil spills. Brine spills may be more frequent than oil spills, and brine is more damaging and less easily recoverable than oil (de Jong 1980; Kennedy 1979).

Reclamation/Abandonment

The operator must submit an abandonment plan and request permission from the U.S. Geological Survey (USGS) to begin abandonment operations. Dry holes and depleted producing wells are plugged with cement. Drilling rigs and support equipment are removed from unsuccessful wells. When an entire lease is abandoned at the end of the production phase, processing, treating, and handling equipment is removed. Surface flow lines are removed, but buried lines are usually plugged and left in place. The surface, including mud pits, must be restored to the requirements of the surface management agency and stipulations of the lease. Earth-moving equipment is used to move disturbed soil back near its original place and to contour the site. Topsoil is replaced and the area is reseeded. Surface rehabilitation may be quite difficult. Access roads may be rehabilitated to previous conditions, abandoned, administratively closed, or left for local residents to use and maintain.

No unique environmental disruptions are likely. Abandonment should result in the removal of most human-associated structures and termination of development-related activity and noise. Wildlife habitat may be restored or improved.

It is oossible that disrupted ecosystems may never be totally rehabilitated, as human settlement occurring during development and production may persist. Moreover, impacts will have been cumulative over many years during the life of the oil field.

IMPACTS ON WILDLIFE

This section summarizes the effects on wildlife behavior, habitat, and populations that may result from the environmental disruptions previously described. The report also includes (1) an index of disturbances (appendix A) keyed to (2) an annotated bibliography (appendix B).

The index is organized by major environmental disruptions (headings) and their primary effects (subheadings). Within each subsection, keywords, relating to numbered references, describe such subjects as the species affected,

the agent of disruption, the specific response of the wildlife, the significance of the effect, the factors affecting degree of response, and special cases of high sensitivity. The outline is based entirely on the information presented in the literature reviewed; therefore, not all subjects are included in each section. The numbers following the keywords direct the user to the annotations, which discuss the effects in more detail. Annotations summarize only data and conclusions judged pertinent to the subject of this paper, and may not represent complete abstracts of entire publications.

The outline and the bibliography must be used together for full benefit. Such a format presents—in the outline—an overall summary of the effects of each disruption. It simultaneously allows research results to be reported—in the annotations—in greater detail and in their original context. This also avoids repetition of results, as many of the publications reviewed address several types of effects and/or disruptions and are pertinent to several sections.

The outline is also intended for use as an index to quickly direct the reader to those subjects of most interest. These may overlap to some extent—such as noise and aircraft disturbance or noise and traffic. However, distinctions were made because of the unique combination of stimuli included in each effect. For instance, aircraft disturbance includes a specific type of visual stimulus as well as a noise component. Traffic activities may include noise and visual stimuli but are distinct because they occur along a fixed corridor.

To facilitate organization, 10 primary effects are distinguished. Papers describing neutral or positive effects on wildlife are also listed. The paper concentrates on primary effects that result directly from a disruption. The significance of the effects is noted when addressed in the literature. For instance, the presence of human-associated structures (disruption) may interfere with movement (primary effect), which, if severe or prolonged, may then result in reduced reproductive success or loss of available habitat (significance). Increased human/wildlife encounters (disruption) may cause animals to avoid an area (primary effect), which, over time, might result in changes in distribution, or alteration of activity patterns or movements (significance). Table 3 summarizes the primary impacts resulting from each environmental disruption. Table 4 shows the significance of primary effects.

This report presents a "worst case" scenario of potential effects. Strategies exist that allow some of these effects to be minimized. Moreover, the severity of an effect is site-specific and depends on such factors as the sensitivity of the species involved, the nature of the disruption, characteristics and importance of the affected habitat, and the availability and condition of alternative habitat (Hanley and others 1980; Streeter and others 1979; USDA 1981b).

Table 3.—Primary impacts potentially resulting from environmental disruptions

	Environmental disruption						
Primary impact	Noise	Aircraft	Human intrusion	Traffic and access	Structures and facilities	Alteration of vegetation/ land	Harmful substances
Interruption of activity/ alarm/flight	x	x	x	x			
Avoidance/displacement	x	x	x	x	x		
Permanent loss of habitat use			x	x		x	x
Decreased reproductive success		x	x				
Interference with movement	x	x	x	x	x		
Direct mortality			x	x	x		x
Interference with courtship	x		x				
Alteration of behavior			x				
Change in community structure						x	

Table 4.—Secondary impacts which may occur as consequences of primary impacts

	Primary impacts									
Secondary impact	Interruption of activity/alarm/ flight	Avoidance / displacement	Permanent loss of habitat	Decreased reproductive success	Interference with movement	Direct mortality	Nest/den abandonment	Interference with courtship	Change in community structure	Alteration of behavior
Decreased use/temporary desertion of traditional areas		x								
Shift in range		x								
Change in distribution		x								
Overutilization/over-population of adjacent habitat		x	x							
Use of marginal habitat		x								
Gradual range abandonment		x			x					
Inefficient use of habitat	x	x	x		x					
Mortality		x						x		
Reduced feeding efficiency	x	x								
Change in activity patterns	x	x								
Interference with/alteration of movements		x								
Decreased availability/ elimination of food source			x			x				
Inadequate nutrition					x					
Insufficient energy reserves for migration					x					
Reduction in numbers			x							
Adverse physiological effects			x		x					
Disruption of social structure/group composition		x			x					
Reduced reproductive potential/success	x		x		x					
Nest desertion		x								
Decrease in nest density/ sites			x							
Delay/failure to den					x					
Den displacement		x								
Decreased survival/loss of young			x		x					
Increased use of alternate nests		x								
Decrease in aquatic productivity			x							
Human injury/property damage										x
Delay/failure to reach traditional range					x					
Ease of travel					x					
Increased vulnerability to predators					x					
Interference with mating synchrony					x					

ENERGETICS OF DISTURBANCE: IMPLICATIONS FOR ANIMAL PHYSIOLOGY

Environmental disruptions may have an additional subtle but important effect on wildlife often overlooked by resource managers. Any changes in an animal's "normal" routine will have some effect on the energy and nutrient budgets of the individual. Energy budgets describe the partitioning of energy flow in the animal body (Hudson and Stelfox 1976). The bioenergetic approach to animal-habitat relationships assumes that "undisturbed animals should exhibit patterns of activity and habitat selection that result in optimization of energy budget" (Morganini and Hudson 1979). Each species possesses strategies to maximize homeostasis and efficiency of nutrient uptake and use, so that a maximum amount of energy is spared from maintenance for reproduction (Geist 1978). Energy expenditure is related to the level of daily activity in addition to maintenance of homeothermy. Deviations from normal activity patterns and habitat use may have profound effects on the energy budget and, therefore, the welfare and productivity of an animal (Burton and Hudson 1978). Negative effects of environmental disruptions (flight, avoidance, interference with movement) raise the energy cost of living at the expense of energy needed for reproduction and growth (Geist 1970). This increased cost results from:

1. The cost of physiological excitement preparing the animal for exertion. This reaction may not be detectable

because the animal "may rigidly control its skeletal muscles while its organ system remains prepared for instant exertion" (Geist 1978). Frequent preparation for flight imposes a burden on the energy budget. Increases in heart rate have been shown to precede or occur in the absence of overt behavioral reactions (MacArthur and others 1979). Geist (1978) states that excitement generally raises an animal's metabolism by about 25 percent above that required for maintenance.

2. The cost of locomotion incurred when an animal attempts to escape a disruption, is forced to deviate from traditional migration routes, etc. This cost varies with such factors as speed, distance, and terrain (Geist 1978). According to Burton and Hudson (1978), flight is the most energetically expensive activity. Geist (1971) calculated a 21 percent increase in cost of living for a caribou, chased by aircraft, which ran for 10 minutes, walked 1 hour, and remained excited for 1 hour more. He determined this expenditure was 3 percent more than the animal's total possible forage consumption. The additional cost must then be drawn from energy stores at the expense of reproduction and growth. The costs of locomotion and excitation are very high compared to normal food intake and energy expenditures (Geist 1978).

3. The cost of lost food intake. An animal responding to a disruption is not able to eat; feeding time is therefore lost. In addition, feeding behavior is dependent on emotional status. Food intake decreases when an animal is disturbed (Hudson and Stelfox 1976).

4. The cost of suboptimal habitat selection. Avoidance of a disruption, interference with movement, and vegetation alteration or destruction may prevent animals from (1) selecting habitats to compensate for adverse climatic conditions, and (2) feeding in preferred areas, where forage is of higher quality or greater availability. The latter may contribute to the decrease in food intake. Low quality forage is digested slowly and therefore cannot be consumed in quantity (Hudson and Stelfox 1976). White and others (1975) found that forage digestibility was an important determinant of the amount of food retained as fat in caribou and reindeer.

If an animal is unable to compensate for such increases in its cost of living, reproduction, growth, and survival may be adversely affected (Geist 1970; Owens 1977). Geist (1979 as cited in Johnson and Lockman) believes that animals can expend relatively little "spare energy" in summer without running an energy deficit. Increased energy costs are most detrimental—for ungulates in particular—during critical times of the year when the animals are already in a state of negative energy balance, e.g., cold weather, late pregnancy, and fly season (especially in northern regions) (Geist 1971 and 1978). During these periods, the energy deficit is increased through the negative effects of disruptions. Increased calf mortality, delayed maturity and smaller body size of adults, reduced survival in winter due to insufficient fat reserves, and decreased reproductive performance may result (Geist 1979 as cited in Johnson and Lockman; Moen 1978). The demands of reproduction are fixed in time (highest in late winter, early spring) and must be met, or productivity is reduced. White-tailed deer produce smaller fawns in late spring when a lack of nutritional forage creates a negative energy balance (Moen 1978). Deer are able to conserve substantial amounts of energy in winter by decreasing their activity. Increasing physical and physiological activity in response to environmental disruptions, however, negates the advantages of this adaptation (Moen 1976). White and others (1975) found that harassment by insects can substantially raise the maintenance energy requirements of caribou by increasing the amount of time the animals spend standing and moving, and reducing feeding and resting time. Additional energy costs at this time may cause disease or even death (Geist 1971).

Ungulates, such as these mule deer fleeing from a helicopter, are one of the major wildlife groups affected by petroleum activities, and are stressed in this review.

The ability of both wild and domesticated reindeer to adapt to changes in their environment and to adjust to disturbances is evidently influenced by the animal's physical condition. Migrations are easily disrupted, and traditional ranges abandoned, when the reindeer are in poor physical shape (Klein 1971). It therefore seems possible that the negative effects of environmental disruptions, by creating an energy deficit that adversely affects an animal's physical condition, may reduce the individual's ability to respond to subsequent disruptions, thereby potentially causing greater energy deficits and accelerating the negative consequences.

MITIGATION

Mitigation[2] may be defined as "a class of actions which have the purpose of counteracting the effects of disruptions on the natural environment and on renewable resources, associated with new physical structures and/or construction activities, and/or management objectives and practices" (Jahn 1979). It refers to "management to reduce, abate, or alleviate an adverse impact." It generally does not refer to complete prevention of impacts, but rather implies that some losses will occur. The goal is to make that loss less severe (Thompson 1979). This section discusses planning for mitigation and describes general approaches for minimizing the adverse impacts of petroleum exploration and development on wildlife including (1) project management, (2) wildlife management, and (3) personnel management.

Planning

The following points should be considered in planning for mitigation:

1. Mitigation is more likely to be implemented when it is an integral part of the original planning process. Wildlife needs and objectives should be considered at the earliest planning stage, i.e., when leasing decisions are made (McGowan 1978; Short and Schamberger 1979; Streeter and others 1979). The sequence of leasing may determine future effects on wildlife. Wildlife biologists may influence this by (1) recommending at this early stage a preferred sequence of development, based on biological values and priorities, which ranks the suitability of lands for development, and (2) by providing alternative leasing possibilities and "trade-off plans" for sensitive areas selected for development. Appropriate mitigation measures may then be incorporated into the initial project design. This strategy may be more effective and manageable than responding to each permit after lease decisions have been made (McGowan 1978; Pamplin 1979; Streeter and others 1979).

2. "An accurate, timely, well-formulated, and complete description of biological resources and their responses to disturbance provides the basis for informed decisions regarding those resources" (Hanley and others 1980). Implementation of baseline studies and development of a comprehensive biotic resource data base describing predevelopment environmental conditions will provide a basis for (1) deciding whether, where, and how to develop, (2) identifying sensitive wildlife and habitats, (3) predicting effects, (4) developing mitigation and monitoring programs, and (5) gaining insights into effects through postdevelopment comparison (Deitz 1979; Hanley and others 1980). The ability to demonstrate the presence of critical wildlife populations or habitats and their sensitivities to potential disruptions will strengthen the wildlife manager's position in the decision-making process and help ensure protection for wildlife. At the early stages of planning for development, resource managers should identify the likely range of wildlife issues, determine what information is needed, and establish tentative priorities for obtaining it. The following points should be considered when making decisions regarding information requirements (Hanley and others 1980).[3]

— Acquire as complete a resource information base as conditions allow.

— Choices must be made about the information that has highest priority, and decisions made about the minimum level of information that allows an accurate and satisfactory estimation of impacts.

— The ultimate goal is to minimize negative effects on wildlife; therefore, emphasis should center on acquisition of information that will help decision makers achieve this goal.

— The detail of information available for a particular site may affect the resource management philosophy applied to the site.

— Information needed for decisions must be available at the right time.

— Information needs tend to become more specific and detailed as the decision process progresses from early to late phases.

— Identification of ecologically sensitive and/or valuable areas is a primary information need during all phases of development.

— Time and money spent on information collection and dissemination should reflect the potential for, and severity of, effects of a proposed activity.

3. Wildlife managers should participate in, and influence, the establishment of stipulations—that is, procedural, environmental, and technical requirements to be met by developers in all phases of activity—to ensure maximum protection of wildlife. These should be based on an evaluation of potential effects and should be included in the lease or right-of-way agreement (Hanley and others 1980; McGowan 1978; Streeter and others 1979). Stipulations may include (1) no surface occupancy on selected areas, (2) restrictions on the season of operation, (3) special reclamation requirements, (4) restrictions on the rate of development and location of wells and facilities, (5) road closure requirements (USDA 1981a), and numerous other measures as necessary. Standard stipulations developed by the land management agency are generally supplemented by special stipulations specific to a project.[4]

4. Provision of a plan to monitor—in the field—development activities, effects on wildlife, and mitigation efforts should be considered essential, and may be included in the lease agreement (Dietz 1979; Pamplin 1979; USDA 1981b). The goals of a monitoring program, as stated by U.S. Department of the Interior (1981b) are as follows:

— To determine if the impact predictions are accurate.

— To discover unanticipated and/or unpredictable impacts.

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[2]A very comprehensive treatment of the subject, including discussions on techniques, planning, problems, evaluation and inventory of habitats and impacts, etc., for many forms of development is available in Swanson (1979).

[3]A very comprehensive discussion of "information needs for natural resource protection during petroleum development" is available in Hanley and others (1980), which can be obtained from the Office of Biological Services, U.S. Fish and Wildlife Services, 1011 E. Tudor Rd., Anchorage, AK 99507.

[4]Consult completed environmental impact statements and Hanley and others (1980) for specific examples of stipulations.

— To determine if mitigation measures are working as prescribed.

— To determine if the action is fulfilling the purpose and need for which it was developed.

— To assist in resolving differences of opinion concerning impacts.

— To assure that decisions are being implemented.

Provisions should be made during the planning stage to allow for modification of ongoing mitigation activities if judged necessary as a result of the monitoring program (Jahn 1979). A unique, interagency surveillance/monitoring system—the Joint Fish and Wildlife Advisory Team (JFWAT)—was organized to provide for the protection of fish and wildlife resources during construction of the Trans-Alaska Pipeline. The team consisted of State and Federal biologists working jointly to ensure compliance with environmental stipulations, address fish and wildlife-related problems developed during the course of development, and offer advice on how best to protect these resources (Kavanagh 1977; Klein 1979; Morehouse and others 1978; Pamplin 1979).[5]

Approaches for Minimizing Negative Effects on Wildlife

PROJECT MANAGEMENT

(Sources: Banfield 1971; Barry and Spencer 1976; Calef and others 1976; Interstate Oil Compact Comm. 1974; Lyon 1975; Miller and Gunn 1980; Pedersen 1978; Stalmaster and Newman 1978; Streeter and others 1979; Stubbs and Markham 1979; Thompson 1979; USDA 1981b; USDI 1976a, 1981a, 1981b; USDI and Fed. Energy Comm. 1981; Ward 1973.)

The development project can be managed by any or all of the following means to minimize negative effects on wildlife. A local data base identifying sensitive species, habitats, and times of year will be necessary for defining restrictions on development.

1. Spatial management

— Avoidance by development activities, roads, facilities, and structures, of locations which are sensitive and/or critical to wildlife, for example, ungulate winter ranges, breeding areas, raptor nests, waterfowl molting and staging areas, critical habitat of endangered species.

— Use of buffer zones or screens to reduce wildlife visual contact with roads and development activity. Buffers may include topographic barriers, vegetation, and/or distance, and are especially recommended for elk and raptors.

— Provision of security areas, especially for ungulates, which contain necessary habitat elements and are sheltered from disturbance. This may be accomplished by restricting roaded activities to one out of two adjacent drainages at any one time. Ridgelines should not be developed in any way.

— Maintenance of security cover in wildlife travel lanes.

— Restriction of aircraft activity to defined flight paths which avoid sensitive areas.

2. Temporal management

— Restriction of activities to seasons and/or times of noncritical wildlife use. Managers should compile a list of dates when development activities should be prohibited in certain locations due to specific needs, such as breeding, calving, migration or local movements, molting (waterfowl), etc.

3. Operational management

— Employment of techniques and methods of development which may reduce negative effects on wildlife. Examples include:

- — Reductions of surface use requirements and facility duplication by joining numerous leases into a unitized field.
- — Coordination of proposed activities to control the number of roads, rights-of-way, etc. Rights-of-way can accommodate several pipelines and/or powerlines to minimize habitat destruction.
- — Use of helicoptor support, where possible, in sensitive areas.
- — Control of aircraft altitude, scheduling, and activities. Following and circling wildlife should be prohibited.
- — Closure of oil field access to unauthorized traffic, and permanent closure and rehabilitation of roads no longer needed.
- — Regulation of oil field traffic to control speeds, numbers of vehicles using the road, and/or timing of use.
- — Design of fences, pipelines, and aboveground structures, and construction of highway underpasses (Reed and others 1975) to minimize interference with wildlife movements.
- — Burial of utility lines in areas with high collision risk for birds.
- — Seeding of roadsides with plant species unpalatable to wildlife and planting "feed plots" away from the road to reduce wildlife-vehicle collisions and poaching.
- — Insulation of noise sources, especially compressor station.
- — Covering, fencing and/or elimination, and eventual rehabilitation, of oil field sump pits.

WILDLIFE MANAGEMENT

The behavior of mammals is influenced by their ability to learn. Teaching animals, by using the principles of learning behavior, can be a management tool used to assist wildlife in adjusting to change resulting from human activity (Geist 1978). Habituation to humans allows wildlife to efficiently use habitat near human activity, without expending large amounts of energy in physiological stress and fear responses (Tracy 1977). According to Geist (1978), animals have the ability to habituate to humans, and are only as wild as we teach them to be.

An animal functions best in a familiar, predictable environment. It learns to respond in definite ways to given stimuli to reduce uncertainty and indecision, and to make adjustments (for example, flight) to achieve a

[5]These references provide further descriptions of JFWAT's organization and operation and give recommendations for the formation of future teams. Hanley and others (1980) also discuss surveillance programs.

familiar environment. It will initially react to an unfamiliar stimulus with a combination of fear and curiosity. The animal's subsequent reactions to the stimulus depend on the experiences associated with it (Geist 1978; Tracy 1977). Geist (1970) states that a wild ungulate's behavior toward humans is largely a consequence of our behavior toward the animal. If an encounter with humans is followed by an alarming event, such as pursuit, the animal will respond to subsequent similar encounters with alarm, flight, and avoidance. If the initial alarm response is not reinforced during the first encounters, habituation will occur. If the animal is rewarded, it will become attracted to humans. An animal may generalize to stimuli which it perceives as similar. Large mammals that are hunted cannot be expected to habituate to hikers, as they will generalize from hunters to other humans (Geist 1978; Tracy 1977). Wildlife will become habituated to predictable events that are not followed by painful and/or harmful events (Geist 1971).

Habituation ability varies among wildlife species and is influenced by the species' learning ability, perceptive abilities, and sensitivity threshold, and by the type of stimulus (Geist 1978; Tracy 1977). Geist lists three types of harassing stimuli for ungulates: (1) those that are not familiar or predictable, (2) those involving sharp contrasts or sudden changes in the environment, for example, quick movements, sudden loud noises, and (3) those to which an animal responds innately with alarm. The latter are generally used to identify dangers present throughout the species' evolution—predators and natural environmental hazards—and are not easily modified by learning (Bergerud 1974). A direct, close approach may produce such evolutionarily based fear responses in a number of species, as it is generally associated with predators (Tracy 1977).

Habituation by wildlife to human activities can be encouraged by (1) avoiding or minimizing fear-provoking stimuli—direct approaches, stalking, loud noises, quick movements, etc.—during human-wildlife encounters, (2) controlling the timing, frequency, and intensity of human activities to make them more regular, and therefore more predictable, and (3) minimizing the frequency and intensity of human-wildlife encounters during times when wildlife are particularly sensitive to disturbance (Tracy 1977).

Habituation may be an advantage to wildlife in many situations, as it allows animals to more efficiently use habitat near human activity. However, in some cases, habituation could be potentially detrimental to wildlife. In particular, animals that adapt to human activity along roads may be more susceptible to poaching, hunting, and collisions with vehicles. Data show that elk habituated to a highway in Glacier National Park and furbearers waiting for "handouts" along the Alaska pipeline haul road have been vulnerable to poaching (Milke 1977; Singer 1975). The feasibility and desirability of encouraging habituation will vary with the situation. Future land use plans and objectives—especially with regard to access—and the ability to control human activity such as hunting, poaching, and use of roads should be considered. The potential benefits and harm to wildlife resulting from habituation should be evaluated for each project. Knowledge of local wildlife populations and their behavior and an understanding of habituation are critical to decisions concerning the compatibility of petroleum development and wildlife.

The large aboveground Alaska pipeline may affect some animal movements, but these grizzly bears moved beneath it.

PERSONNEL MANAGEMENT
(Sources: Streeter and others 1979; Stubbs and Markham 1979; USDA 1981b; USDI 1976a; USDI and Fed. Energy Reg. Comm. 1981).

The negative effects of petroleum development on wildlife can be further reduced by regulating the activities of oil field workers to minimize interactions with wildlife.

The following methods are suggested:

— Company provision of housing and/or camping areas in locations that avoid sensitive wildlife areas (elk meadows and desert bighorn and quail water sources), and restrictions on "squatting" in such critical areas.

— Busing of employees from living quarters to the work site. This has been shown to significantly reduce the incidence of poaching (Streeter and others 1979).

— No firearms on the project site and in vehicles using oil field access roads.

— No recreational off-road vehicles on oil field access roads.

— Specifications for garbage and food handling and disposal to prevent wildlife attraction.

— No feeding of animals.

Regulations must be backed by cooperative enforcement, effective penalties, and a firm commitment by management (USDI 1976a; USGS 1979). In addition, petroleum companies may be required to provide environmental education programs for all personnel, including truck drivers (USDI 1976a). Such a program might discuss: (1) basic concepts of ecology and animal behavior, (2) rules, regulations, and suggestions for minimizing the effects of human activity on the environment, (3) the biotic resources found in the area, and (4) the ethics and responsibilities involved in outdoor recreation. The Overthrust Industrial Association[6] (1981c) is planning an Environmental Awareness Training Program.

CONCLUSIONS

Research on the potential effects of human activities on wildlife has concentrated primarily on documenting observable, behavioral responses of wildlife to human-caused disturbance. Many results are conflicting. Few studies have conclusively demonstrated the effects of human activities on the survival or productivity of wildlife populations. This may not be easily shown due to the number of factors involved (Jingfors and Gunn 1981), the lack of environmental control, and the difficulties in devising appropriate methodology. Moreover, it is often difficult to separate natural variations in population from human-caused variations without baseline, predisturbance data (Hanley and others 1980). Such data have not been available for many studies, which were initiated in response to environmental disruptions from ongoing activities. Efforts should be made to gather baseline data which will allow more definitive conclusions from future studies, based on long-term comparisons of predisturbance and postdisturbance data. Until such results are available, wildlife managers will have to rely on behavioral observations and generalizations if they are to minimize the negative effects of current development. The following conclusions may be drawn from the literature currently available:

1. The potential effects of petroleum development on wildlife in wildland environments are numerous and varied.

2. The severity of the effect is site-specific and depends on such factors as (a) the sensitivity of the species affected, (b) the nature of the disruption, (c) the characteristics and importance of the affected habitat, and (d) the availability and condition of alternative habitat.

3. The major wildlife groups affected, as reflected by emphasis in the literature, are ungulates, carnivores, water birds, upland birds, and raptors. Small birds and mammals may be affected in large numbers, but generally only locally. They are more capable of rapid recovery because of their high reproductive rate and wide distribution.

4. Response to disruptions varies among species and/or individuals and is dependent on numerous factors including: (a) the previous experience of the animal with a given disruption, (b) characteristics of the disruption, (c) characteristics of the habitat, (d) characteristics of the animal and/or group, and (e) timing of the disruption in relation to critical periods of the animal's life cycle.

5. The effects of petroleum development may be most critical in certain highly sensitive situations including: (a) during times when animals are already stressed by natural conditions, (b) in habitats traditionally used by populations during critical periods of their life cycle, (c) for species whose social organization and/or behavior makes them particularly susceptible to disturbance, and (d) for certain sex/age groups of animals.

6. An understanding of general concepts of animal behavior and energetics is necessary to fully comprehend the consequences of petroleum development activities on wildlife.

7. Negative effects can be minimized by numerous means, including project, wildlife, and personnel management.

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APPENDIX A: BIBLIOGRAPHIC INDEX

Numbers refer to entries in annotated bibliography.

Noise

Table 5.—Maximum land areas avoided by wildlife due to noise of pipeline surveillance aircraft flying at 500 ft (table 3.1.1. 15—5 in reference 103)

Wildlife	Season or activity	Estimated total pipeline miles[1]	Estimated maximum area (mi^2) avoided by wildlife
Caribou	Calving	58	19
	Postcalving aggregation	38	12
	May/June	90	30
	July/August	58	19
Sheep	Summer range	13	26
Moose	—	8	1
Grizzly bears	—	99	32
Snow geese	Premigratory staging grounds	77	770

[1]Data supplied by Northern Engineering Services Co., Ltd.

Significance

decreased use of traditional areas 10, 42, 58, 102, 103, 111
nest desertion 104

Factors influencing magnitude of effect

experience associated by animal with sound 14, 38, 46, 58, 104
unexpected sounds 14, 81
regularity/frequency of noise 2, 14, 22, 33, 38, 58, 81, 98, 104
sound localization/extent of influence 38, 58, 102
intensity of noise 2, 102, 111
proximity of sound 104
combination of sound with visual stimulus 14, 70, 98
biological state of animal 14, 33, 98
activity of animal 33
season 103

Highly sensitive situations

initial exposure to noise 14, 22
sudden loud noise 14, 98
staging geese 10
winter 98
calving 98
female/young 100, 104
breeding 14, 33
colonial nesters 22

3. **Interference with Movement**

Species affected

caribou 103
snow geese 10, 103

Highly sensitive situations

staging geese 10, 103

Agent of disruption

compressor station simulation 10, 103

Specific effect

deflection of movement 10, 103

Significance

insufficient energy reserves for migration 10, 103

4. **Interference with Courtship**

Species affected

general 72
prairie chicken 107

Agent of disruption

oil field operations 107

Specific effect

masking of courtship signals 72, 107

5. **Neutral/Positive Effects**

Species affected

general 14, 22, 38, 102
moose 70
reindeer 33, 98
caribou 104
Dall sheep 104
mountain goat 90
elk 111
lambs 2
bald eagle 94
geese 81
falcons 104
wild turkey 66

Agent of disruption

tourists 90
trains 90
industrial activity 38
sonic boom 33, 66
blasting 104
shooting 81
airport 14, 38
traffic 70, 111
construction 104

Aspect

behavioral reaction to noise - all references
use of noisy areas 14, 38, 102, 104
productivity 66

Aircraft Disturbance

1. **Interrupted Activity/Flight**

Species affected

Dall sheep 103
musk-ox 76, 77
pronghorn 65
caribou 6, 15, 41, 56, 76, 103
moose 56, 103
reindeer 98
grizzly bear 44, 56, 87, 103
wolf 103
shorebirds, waterfowl 7, 13, 120
snow goose 10, 105
Canada goose 103
brant 81, 89
common eider 103
raptors 103

Agent of disruption

helicopter 6, 7, 15, 41, 44, 56, 65, 76, 77, 81, 87, 89, 103, 120
fixed-wing aircraft 6, 15, 44, 56, 81, 89, 103

Factors influencing magnitude of effect

animal's previous experience with disruption 44, 56, 65, 77, 87
aircraft altitude 7, 10 15, 56, 65, 76, 81, 103, 105
aircraft distance 65, 76, 81, 103
aircraft flight characteristics 15, 76, 77, 81, 103
noise 65, 81
type of aircraft 6, 10, 15, 44, 56, 81, 87
animal's experience with being hunted, captured from aircraft 44, 87, 103
timing of overflights 76, 77, 89
season 15, 56, 103
degree of insect harassment 15, 56
rutting activity 77
recent exposure to wolf attack 77
activity of animal 15, 56, 76, 103
presence of calves 76
size of group 15, 56, 76, 103
separation of cow and calf 41
terrain 76, 103

Highly sensitive situations
incubating birds 103
staging geese 10, 105
calves 15, 41
female/young 15, 41, 56, 76, 103
molting waterfowl 89
winter 15, 103
calving 15
rut 15
insect season 15, 56
animals hunted/captured from aircraft 44, 87, 103
landing/combination with human disturbance 76, 77
low altitude flights 7, 56, 65, 77, 81, 105
circling/following 15, 76, 77, 103
helicopters 6, 7, 15, 44, 56, 81, 87, 103

2. **Avoidance/Displacement**
(refer also to table 5)

Species affected
musk-ox 103
Dall sheep 103

Agent of disruption
helicopter 103

Significance
decreased use of traditional area 103
temporary desertion of area 103
shift in summer range 103

3. **Decrease in Reproductive Success**

Species affected
shorebirds, waterfowl 7, 103
brant 103
bald eagle 103
grizzly bear 87

Factors influencing magnitude of effect
combination with on-the-ground human disturbance 103

Agent of disruption
helicopter 7, 87, 103
nest survey 103

Specific effect
lower nest success 103
decreased production of young 103
loss of eggs 7, 103
nest abandonment 103
den abandonment 87

4. **Interference with Movement**

Species affected
caribou 6

Agent of disruption
jet-copters 6

Specific effect
alter direction of travel 6

5. **Neutral/Positive Effect**

Species affected
musk-ox 76, 77, 103
deer 65
moose 56
caribou 6, 15
wolf 56, 71, 103
waterbirds 13, 103, 120
wading birds 60
brant 89
oldsquaw 120

Factors influencing magnitude of effect
frequency of exposure/airfield nearby 65, 103, 120
animal's previous experience with disruption 56, 71, 76, 77, 103
aircraft altitude 6
type of aircraft 6
timing of overflights 76, 77
season 15
lack of negative associations by animal 71, 103

Agent of disruption
float plane 103
helicopter 6, 15, 60, 65, 76, 77, 120
fixed-wing aircraft 6, 60, 71, 103

Aspect
behavioral reaction to aircraft - all references
nest density 120
herd splintering 76, 77
range abandonment 76, 77
abandonment of calves 15

Increase in Human/Wildlife Encounters

This section considers the increasing wildlife-human encounters, both direct and indirect, resulting from the greater human demand on wildlife habitat that accompanies oil field exploration and development. It includes (1) activities directly associated with specific development operations and facilities (generally localized and predictable) and (2) secondary activities related to increases in population and access resulting from oil field development (generally widespread, less predictable, and permanent). Traffic and road-related activities are discussed separately.

1. **Interrupted Activity/Flight**

Species affected
bighorn sheep 48, 59, 64, 114
elk 1, 88, 90
deer 9, 11, 84
moose 1, 70
caribou 25
mountain goat 90
brown bear 100
wolf 19, 71
waterbirds 13
common loon 99
brant 81
bald eagle 94
osprey 3

Significance
reduced nest success 3, 99
reduced feeding efficiency 81

Agent of disruption
recreation 3, 13, 19, 81, 99, 100
approach by human 1, 11, 19, 25, 48, 59, 64, 70, 71, 88, 90, 94, 114
harassment 88
human scent 100
snowmobile 11, 84

Highly sensitive situations
female/young 1, 25, 64
incubation 99
ground nesting birds 3
adult or feeding bald eagles 94

Factors influencing magnitude of effect
animal's previous experience with disruption 1, 9, 19, 70, 90, 94, 99, 100
manner of human approach 1, 48, 59, 64, 70, 84, 88, 99, 114
proximity of activity 13, 19, 25, 48, 94
amount of movement 13
terrain, vegetation 1, 19, 84, 94
animal group size 1, 25, 48
age of animal 94
activity of animal 70
physiological status 1
relation of cover 13, 48, 64, 70, 84

2. **Avoidance/Displacement**

Species affected
large mammals 36
elk 58, 63, 67, 82, 111, 112, 113, 121
deer 26, 30, 50
pronghorn 107
red deer, chamois 8
caribou 16, 57, 120
bighorn sheep 17, 62, 114
large predators 106

Specific effect

destruction of "nuisance" animals 42, 74
vehicle collisions 74
poaching 74

7. **Interference with Courtship**

Species affected

elk 58, 63, 88
caribou 23
upland birds 107, 108

Agent of disruption

approach by humans 88
seismic operations 58
oil field construction 107, 108
general human activity 23, 63

Specific effect

temporary disruption of breeding group activity 58, 63, 88
interference with timing/mating stimuli 23
abandonment of courtship grounds 107
disturbance of courting males 108

8. **Alteration of Behavior**

Species affected

bears 38, 39, 42, 45, 84, 91
wolf 74
fox 29, 74

Significance

destruction of "nuisance" animals 74
human injury/property damage 74, 91

Agent of disruption

wildlife feeding 42, 74, 91
improper food/garbage storage 42, 74, 91
human/bear encounters 39, 91

Specific effect

loss of fear of humans - all references

9. **Neutral/Positive Effect**

Species affected

elk 58, 88, 111
moose 70
deer 11, 26, 30, 73
bighorn sheep 48, 114
brown/grizzly bears 44, 100
wolf 19
arctic fox 29
waterbirds 7, 13, 120
common loon 99
oldsquaw 120
herons 101
upland birds 73
bald eagle 80, 94
small mammals 73

Agent of disruption

oil field operations 7, 29, 44, 58, 120
recreation 13, 48, 88, 99, 114
construction 73, 111
presence/approach by humans 19, 70, 80, 94
harassment 88, 101
snowmobile 11, 26, 30

Aspect

wildlife numbers 7, 44, 48, 73, 80, 114, 120
reproductive success 99, 101, 120
nest density 80, 120
distribution 44, 58, 88
reaction to humans 13, 19, 29, 70, 94, 99, 100, 120
movements 11, 26, 30, 48, 58
use of traditional areas - all references except 11, 70, 94, 99, 101, 120

Traffic and Access-Related Activities

These activities are considered separately from other cases of human intrusion as some effects are unique to roads and rights-of-way, and a considerable amount of literature addresses this particular subject.

1. **Interrupted Activity/Flight**

Species affected

caribou 51, 100
elk 88, 90, 111, 113
pronghorn 12
moose 100
Dall sheep 100
wolf 100
fox 100
hare, porcupine 100

Significance

change in activity patterns 12, 100
inefficient use of habitat 100

Highly sensitive situations

young calves 100
male fox 100
winter range 12

Factors influencing magnitude of effect

vehicle stopping 88, 100, 111, 113
people leaving vehicle 88, 100, 111, 113
animal group size 100
sex 51
distance 90
daylight 88
cover 51
noise 100

2. **Avoidance/Displacement**

Species affected

elk 40, 47, 67, 68, 79, 82, 83, 85, 86, 88, 111, 118, 121
caribou 16, 57, 100
deer 83, 85, 86
brown bear 100
wolf 100
hare, porcupine 100

Agent of disruption

interstate 111, 113
park road 88, 100
forest road 68
primary/secondary road 47, 82, 83, 118
Alaska Pipeline haul road 57
oil field access road 121

Significance

decreased use of areas near road - all species references
change in distribution 16, 67, 79, 100
change in activity patterns 40, 79, 88, 100
inefficient use/use of marginal habitat 68, 79, 82, 118
alteration of movements 57
den displacement 100
change in group composition 16

Factors influencing magnitude of effect

road density 47, 82, 85, 100, 111, 118
intensity of road use 47, 82, 86, 87, 88, 100, 111, 118
type of road 47, 82, 83, 85
proximity to road 47, 68, 79
slope aspect 83
food/habitat availability 85, 86, 88, 100
openness of habitat 68, 79, 85, 86
presence of cover/screen 16, 67, 83, 111
season 16, 82
animal's previous experience with disruption 100
hunting 40, 47, 79

Highly sensitive situations

road crossing traditional use area 47, 79, 83
winter range 79, 85, 86
open areas 16, 68, 79, 83
construction of new roads 67, 82
female/young 16, 57, 118
hunted population 47

3. **Reduction in Available Habitat**

Species affected

elk 83, 118
reindeer 54
brown/grizzly bear 31, 87
shorebirds 100

Highly sensitive situations

high use wildlife areas 83
river bottoms 87

Significance

decrease in nest density 110
reduction in wildlife numbers 31, 87

Factors influencing magnitude of effect

traffic volume 110
road density 31
presence of cover 31, 83
slope aspect 83
presence of railroad 54

4. **Interference with Movement**

Species affected

elk 47, 111, 113
reindeer 54
caribou 100
mountain goat 90
Dall sheep 100
pronghorn 12
wolf 100
fox 100

Agent of disruption

interstate 111, 113
park road 90, 100
primary/secondary road 12, 47, 54
railroad 54

Factors influencing magnitude of effect

snow depth 12, 47
intensity of activity 12, 47, 90, 100
herd size 90, 100
migration 100
time of day 90
direction of travel 90
sex, age of leader 90
presence of cover 90

Specific effect

delay/barrier 54, 90, 100, 111, 113
use of access corridors as travel lanes 47, 100

5. **Direct Mortality**

Species affected

big game 95
elk 32, 47, 90
reindeer 54
mountain goat 90
furbearers 57
grizzly bear 87
raptors 32, 106
hare 100
general 57, 106, 109

Specific effect

poaching 32, 57, 87, 90, 95, 106
increased hunter access 32, 47, 90, 95, 106
vehicle collision 54, 90, 100, 106, 109

Highly sensitive situations

road close to migration routes/winter range 90
wildlife habituated to activity 54, 57, 90
open terrain 57
raptors using utility pole perches 32
winter 54

6. **Neutral/Positive Effects**

Species affected

elk 83, 88, 90, 111, 112, 113
caribou 100
reindeer 54
deer 18, 83
Dall sheep 100
moose 100
wolf 100
fox 39, 100
oystercatcher 110

Aspect

use of traditional areas 29, 83, 88, 100, 110, 111, 112
behavioral reaction to traffic 29, 54, 88, 90, 100, 111, 113
wildlife numbers 18
activity 112
nest density 110
raising of young 29

Presence of Human-Associated Structures and Facilities

This section addresses the effects of the physical presence of man-made structures (pipelines, powerlines, fences, roads, rights-of-way) existing in the absence of immediate human activity. It is assumed that an animal's response to a structure may be influenced, to some unknown degree, by its previous association with human activity.

1. **Avoidance/Displacement**

Species affected

general 32
caribou 49
wolf 71

Agent of disruption

right-of-way 32
pipeline 49
objects with recent human scent 71

Significance

interference with movement 49

2. **Interference with Movement**

Species affected

large mammals 55
elk 113
pronghorn 12
caribou 6, 23, 43, 49, 75, 78, 100

Significance

delay/failure to reach traditional range 6, 23, 75, 78, 100
reduced calf survival 75, 78
easier travel 6, 100
increased vulnerability to predators 6
interference with mating synchrony 23
disruption of social structure 23, 75
inefficient habitat use/abandonment of traditional areas 55, 75, 100

Agent of disruption

pipeline 43, 49, 75
road 100
fence/corral 12, 78, 113
rights-of-way/seismic trails 6
general physical barriers 23, 75

Factors influencing magnitude of effect

age/sex composition of group 43, 49
size of group 100
animal's previous experience with disruption 43
degree of insect harassment 43, 49
timing 49, 100
height of berm 43

Specific effect

delay/barrier - all references except 6
use of corridor as travel lane 6, 100
diversion of movement direction 6, 43, 49, 75, 100

Highly sensitive situations

female/young 23, 43, 75, 78, 113
pregnant female 6, 75, 78
breeding groups 23
calving/postcalving areas 75

3. **Direct Mortality**

Species affected

waterfowl 21, 32, 106, 117
cranes 32, 97
eagles 117
general 32, 117

Specific effect

collisions with utility lines - all references
oil field sumps 106

Highly sensitive situations

poor visibility conditions 97, 117

4. **Neutral/Positive Effects**

Species affected

general 42, 102
caribou 6, 43, 49, 78, 100
Dall sheep 100
elk 32, 111, 113
deer 32
wolf 71
arctic fox 29
raptors 93

Aspect

additional food, perch, nest sites 32, 42, 93
use of area near road/right-of-way 32, 42, 100
reaction to man-made structures 29, 32, 71, 102
winter use of seismic trails 6
use of pipeline crossing facilities 49
road crossing 100, 111
berm crossing 43
movement 78, 113
density 93
corridor crossing 32

Factors influencing magnitude of effect

height of berm 43
degree of noise/movement 102
fresh human scent 71
animal's previous experience with disruption 43, 49
age/sex composition of group 49
degree of insect harassment 43, 49
timing 49

Disturbance of Vegetation or Land Surface

1. **Reduction in Available Habitat**

Species affected

general 42, 92, 102, 106
big game 61
elk 82
deer 69, 73
bighorn sheep 119
brown bears 31
small mammals 73
upland birds 73

Highly sensitive situations

winter range 69, 92, 119
breeding areas 42, 92

Agent of disruption

road 31, 73, 82
mining 61
oil field operations 42, 106
livestock 119
subdivision 69
general development 92
summer cabins 31

Significance

decrease in aquatic productivity/food availability 102, 106
reduction in wildlife numbers 31, 69, 92, 119
decreased reproductive potential 42, 69
disease 119
decreased lamb survival 119
elimination of nest sites 42

2. **Change in Community Structure**

Species affected

deer 73
birds 4, 5, 73, 120
small mammals 73

Factors influencing magnitude of effect

width of corridor 5

Agent of disruption

transmission line corridor 4, 5
drilling 120
road/right-of-way 73

Specific effect

change in species composition 4, 5, 73, 120
change in species diversity 4, 5

Introduction of Harmful Substances into the Environment

1. **Reduction in Available Habitat**

Species affected

general 42, 53, 108
birds 42

Agent of disruption

natural gas leak 108
fuel, crude oil, mud spill 42
"dust shadow" from vehicle activity on gravel 42
brine spill 53

Specific effect

destruction/alteration of vegetation 42, 53, 108
loss of nesting habitat 42

2. **Direct Mortality**

Species affected

general 42, 106, 107
waterfowl 20, 52, 107
livestock 52

Agent of disruption

toxic amounts of hydrogen sulfide gas 106, 107
oil field storage pits (evaporation, sludge, etc.) 20, 52, 107
water pollution 42

APPENDIX B: ANNOTATED BIBLIOGRAPHY

1. Altmann, M. The flight distance in free-ranging big game. Journal of Wildlife Management. 22(2): 207-209; 1958.

The author concluded that numerous factors can influence the flight distance (distance to which a person can approach a wild animal without causing it to flee) of moose and elk, including reproductive and nutritional status; habitat; individual variation based on previous experience of animal. Long flight distances were observed during hunting season, for moose cows with calves, when author approached animal silently and under cover, and for single animals or those on the periphery of a group. Short flight distances were observed during rut, during winter, when animal approached by noisy tourists in area frequented by tourists, and for animals in a close group. In areas of rare human presence, elk were not wary. A longer flight distance was associated with the presence of vegetative cover.

2. Ames, D. R. Physiological responses to auditory stimuli. In: Fletcher, J. L.; Busnel, R. G., eds. Effects of noise on wildlife. New York: Academic Press; 1978: 23-45.

Experiments with lambs exposed to various sounds for 12 days found sound to be a stressor (any stimulus which provokes a response similar to those attributable to increased levels of ACTH or adrenocorticotropin, a hormone, released as a result of stress). Lambs appeared to show differentiation in response to sound level, intensity, and duration. Exposure to 75 dB and 100 dB sound caused significant changes in heart rate and breathing. Evidence of acclimation to sounds less than 100 dB was shown.

3. Ames, P. L.; Mersereau, G. S. Some factors in the decline of the osprey in Connecticut. Auk. 81(2): 173-185; 1964.

Reports incidence of ground-nesting osprey destroying eggs when flushing in response to rapid approach by speed boats. Birds apparently attempt to escape discovery by remaining on the nest as long as possible, then flushing directly from the incubation position, which increases the chance of eggs being crushed or pushed from the nest.

4. Anderson, S. H. Changes in forest bird species composition caused by transmission-line corridor cuts. American Birds. 33(1): 3-6; 1979.

Bird surveys before and after construction of a 150-ft wide transmission line in eastern deciduous forest showed (1) an increase in species composition and number of species, (2) a significant decrease in species diversity, (3) a decrease in the number of migrant and canopy-foraging species, and (4) an increase in species associated with grassland and edge (unstable) habitats.

5. Anderson, S. H.; Mann, K.; Shugart, H. H., Jr. The effect of transmission-line corridors on bird populations. American Midland Naturalist. 97(1): 216-221; 1977.

Observations of bird populations along four widths—40, 100, 200, 300 ft—of transmission line corridors in eastern deciduous forest showed that the 100-ft corridor had highest bird density and diversity, and seemed to increase the "edge effect" to the greatest degree. Narrower corridors showed the least change from a forest-bird community. Wide corridors tended to support grassland communities of birds not characteristic of the surrounding forest. The greatest species diversity was associated with forest habitat. Conversion of forest to corridor tended to selectively displace permanent resident species.

6. Banfield, A. W. F. The relationship of caribou migration behavior to pipeline construction. In: Geist, V.; Walther, F., eds. The behavior of ungulates and its relation to management. I.U.C.N. Publication New Series No. 24. Morges, Switzerland: International Union for Conservation of Nature and Natural Resources; 1971: 797-804.

Studies indicate that caribou tend to choose travel routes offering easiest walking condition. Migrating caribou on winter range have been observed to follow seismic lines for some distance, eventually turning off if the line departs from their normal route. Potential hazards of this practice include (1) increased vulnerability to wolves, (2) delay or failure to reach traditional calving grounds by pregnant females following lines too far, and (3) diversion of migration from normal route. These hazards are also associated with buried gas pipeline corridors.

Author suggests that most caribou herds are habituated to planes, but not helicopters, flying at heights of at least 1,000 ft. New jet-copters appear especially disturbing and often cause animals to change their direction of travel.

7. Barry, T. W.; Spencer, R. Wildlife response to oil well drilling. Progress Note No. 67. Ottawa, ON: Canadian Wildlife Service; 1976. 15 p.

The effects of oil drilling in the Mackenzie River delta were studied during one summer. Within 1.5 mi of the drilling rig, 43 percent of bird species were significantly less numerous than normal, 52 percent were unaffected, 5 percent were more abundant (ravens, whimbrels using area traditionally for nesting). No generalizations were possible as great variations in effect were indicated. Some species showed signs of habituation. Geese and swans, when molting or with downy young, moved or stayed at least 1.5 mi from the rig. White-fronted geese moved out of both rig and control (5mi away) areas. Hatching success was greater in the control area than the rig area.

Low-flying helicopters appeared to be the most disturbing factor, directly affecting a circle of at least 1.5 mi radius. Increased predation was observed on nests from which birds were disturbed. Disturbance decreased with increasing flight altitudes.

8. Batcheler, C. L. Compensatory response of artificially controlled mammal populations. Proceedings: New Zealand Ecological Society. 15: 25-30; 1968.

Analysis of data on red deer and chamois controlled by hunting indicates that favorable response to reduction in numbers (e.g., improved physical condition, increased reproduction) may be suppressed "when the control technique disrupts the ability of survivors to exploit preferred . . . habitat." Animals responded to increasing hunting pressure by using nonpreferred, marginal habitat

and remaining on summer range during winter. Consequently, animals were in poorer condition and the young:female ratio decreased.

9. Behrand, D. F.; Lubeck, R. A. Summer flight behavior of white-tailed deer in two Adirondack forests. Journal of Wildlife Management. 32(3): 615-618; 1968.

Comparisons of summer flight behavior of white-tailed deer on hunted and unhunted areas support the hypothesis that response to people is greatly modified by experience. The flight distance for antlered deer on the hunted area was significantly greater than for antlerless deer on both areas.

10. Berger, T. R. The Berger report: northern frontier, northern homeland. Living Wilderness. 41(137): 4-33; 1977.

Snow geese staging for migration are highly sensitive to human presence, noise, and aircraft. Researchers have found that geese would not feed closer than 1.5 mi from a device simulating compressor station noise. Birds flying over it diverted their course by 90° or more. Geese flushed in response to aircraft flying at considerable distances (2 mi) and heights (8,000-10,000 ft). Deliberate harassment cleared flocks from a 5- by 10-mile area in 15 minutes.

Caribou are very sensitive during calving and postcalving periods. Disturbance preventing or delaying arrival at calving grounds can force calving in unsuitable areas and increase loss of young. The greatest loss of calves occurs in the postcalving aggregation when caribou are stressed by insects, nursing, and antler growth. Repeated disturbance by unfamiliar sights or noises may force caribou from their traditional range.

11. Bollinger, J. G.; Rongstad, O. J.; Soom, A.; Eckstein, R. G. Snowmobile noise effects on wildlife, 1972-1973 report. Madison, WI: University of Wisconsin, Engineering Experiment Station; 1973. 85 p. (Cited in Bury, R. L. Impact of snowmobiles on wildlife. Transactions of the North American Wildlife and Natural Resources Conference. 43: 149-156; 1978. Original not seen.)

This study found no increase in deer movements or change in activity patterns in response to snowmobiles. Deer seemed to react more to the sight than the noise of snowmobiles. Deer were observed to remain close to persons working with chain saws, but move away when a person tried to walk near them. Some disturbance was possible as snowmobiles initially moved into an area.

12. Bruns, E. H. Winter behavior of pronghorns in relation to habitat. Journal of Wildlife Management. 41(3): 560-571; 1977.

This study found that roads and fences were important in determining pronghorn use of winter range in Alberta. Four-strand barbed wire fences presented a major obstacle to pronghorn. The herd was generally within 0.3 mi of a highway, but tended to avoid crossing, probably due to traffic and snow in ditches. Pronghorn demonstrated low levels of daily activity, with breaks in the foraging-resting pattern caused by the approach of vehicles or predators.

13. Burger, J. The effect of human activity on birds at a coastal bay. Biological Conservation. 21(3): 231-241; 1981.

This research concerned the effects of various human activities on nonbreeding waterbirds in the New York City refuge near Kennedy Airport. Data showed that birds were present at a site more often in the absence than the presence of people. Responses to human activities varied according to the location and species of bird and the nature of the activity. Birds generally flushed in response to rapid and/or close movement. Herons, egrets, and shorebirds were most easily disturbed, often flying to distant marshes. Birds on water flushed least often; those on the beach most often. Birds generally did not respond to subsonic jets. They always flushed in response to the SST passing overhead, but often returned to their original position. The author believes that the presence of gulls near airports does not necessarily prove that the birds are undisturbed by noise. The airport may be the safest—or only—foraging/loafing area.

14. Busnel, R. G. Introduction. In: Fletcher, J. L.; Busnel, R. G., eds. Effects of noise on wildlife. New York: Academic Press; 1978: 7-22.

The author states that "wildlife reactions to noise are difficult to define or predict." Reactions vary considerably between and within species, depending on the biological state of the animal, the season, population density, physical parameters of the noise, and so on. Distinction must be made between permanent noise sources and intermittent and mobile sources. Transient loud noises generally provoke alarm. An animal's first reaction to a new noise is fear and avoidance. Many animals apparently learn to ignore noise that is not associated with negative experiences, for example, being chased. The negative association of a sound with humans may provoke avoidance. An unusual noise in combination with a visual stimulus (aircraft) may be particularly disturbing. It is difficult to determine if a response is due to noise alone.

15. Calef, G. W.; DeBock, E. A.; Lortie, G. M. The reaction of barren-ground caribou to aircraft. Arctic. 29(4): 201-212; 1976.

During spring and fall migration, the percentage of panic responses (animals out of control) and strong escape responses (trotting or running, continuing after aircraft passed) was high at aircraft altitudes of less than 200 ft, and decreased with increasing altitude. Only mild responses were observed at altitudes above 500 ft. On calving grounds and during early winter cold, a high percentage of panic and strong escape responses was observed at all altitudes up to 500 ft, with little decrease in response with increasing altitude. In contrast with other studies, fixed-wing aircraft provoked a greater response than helicopters. Following caribou with a helicopter once they started moving caused extreme panic. Cows did not abandon calves in five cases of low overhead passes or helicopters landing nearby. Calves appeared more reactive than other caribou during spring and fall. Cows with calves appeared no more sensitive than other caribou during fall. Caribou at river crossings were more reactive. Group size, terrain, and vegetation type had no significant effect on response. The authors discuss contrasting results obtained by other researchers. An altitude of 1,000 ft is suggested for aircraft to avoid provoking injurious responses.

16. Cameron, R. D.; Whitten, K. R.; Smith, W. T.; Roby, P. D. Caribou distribution and group composition associated with construction of the Trans-Alaska pipeline. Canadian Field-Naturalist. 93(2): 155-162; 1979.

This study evaluated the seasonality of caribou response to pipeline and construction activity. Regional comparisons of survey data show corridor-related abnormalities in caribou distribution and group composition. Avoidance of the Prudhoe Bay area, traditionally a part of the herd's calving grounds, was noted throughout the study, though use of adjacent regions continued. Changes near Prudhoe Bay reflect the pattern of disturbance-related abandonment of range, which is thought to be a gradual process occurring with increasing avoidance of adverse stimuli. Summer avoidance of the haul road corridor was primarily by cows with calves. Greater visibility on the flat coastal plain may influence the degree of avoidance because of the importance of visual stimuli to caribou. Prudhoe Bay avoidance continued during fall; but cow/calf avoidance of the corridor decreased.

17. Campbell, B.; Remington, R. Influence of construction activities on water-use patterns of desert bighorn sheep. Wildlife Society Bulletin. 9(1): 63-65; 1981.

Watering activities of desert bighorn sheep changed significantly after construction was begun near a traditional water source. Under undisturbed conditions, peak watering activity occurred between 6 a.m. and 8 a.m. To avoid human disturbance, bighorn visited water (1) during the short period between dawn and start of work, and (2) after the work day. No visits occurred between 6 a.m. and 2 p.m. while construction was in progress. Such a shift results in inefficient energy use and, potentially, lower reproductive output. Normal activity patterns allow minimum energy to be expended in obtaining water by visiting during the coolest parts of the day. Habitat near the water source may be overutilized if sheep use the area for bedding to avoid night travel.

18. Carbaugh, B.; Vaughan, J. P.; Bellis, E. D.; Graves, H. B. Distribution and activity of white-tailed deer along an interstate highway. Journal of Wildlife Management. 39(3): 570-581; 1975.

This study analyzed white-tailed deer distribution and activity along forested and agricultural sections of an interstate. The impact of the highway on deer abundance and distribution and the relationship between deer activity and vehicle collisions were found to be functions of the highway location relative to deer requisites (feeding and resting sites) and to availability of feeding areas other than the right-of-way. No relationship was observed between traffic volume and numbers of deer seen.

19. Chapman, R. C. Human disturbance at wolf dens - a management problem. In: Linn, R. M., ed. Proceedings, first conference on scientific research in the National Parks; 1976 November 9-12; New Orleans, LA. Vol. 1. Transactions and Proceedings Series No. 5. Washington, DC: U.S. Department of the Interior, National Park Service; 1979: 323-328.

Wolf response to humans near pups was highly variable, ranging from no response to flight, temporary abandonment of pups, or movement of pups from the den. Pup mortality was not reported. Disturbance of den areas prior to whelping may influence den selection. Response to disturbance appears dependent on the number and social position of wolves at the home site, the wolves' previous experience with humans, and severity of the disturbance. Wolves were generally not disturbed by humans further than 0.5 mi in open areas and 0.25 mi in forested areas. Wolves regularly den within 1.5 mi of established human activity centers in the park. The author considers this a "safe" distance for exclusion of human activity in open areas. Smaller areas may be adequate in forested areas. Wolves that are more shy of humans may require larger closed areas.

20. Childress, J. The impacts of energy development on Colorado's wildlife. Proceedings Western Association Fish and Wildlife Agencies. 51: 196-201; 1978.

Passage of a federal law requiring covering of oil pits has reduced loss of waterfowl to these ponds.

21. Cornwell, G.; Hochbaum, H. A. Collisions with wires - a source of anatid mortality. Wilson Bulletin. 83(3): 305-306; 1971.

Observations on northern prairie breeding grounds suggest that duck collisions with overhead wires are common, though generally unnoticed and unreported. Transmission lines can become a frequent local source of duck mortality. The authors suggest that alternatives to running overhead lines through marshes be considered.

22. Cottereau, P. Effect of sonic boom from aircraft on wildlife and animal husbandry. In: Fletcher, J. L.; Busnel, R. G., eds., Effects of noise on wildlife. New York: Academic Press; 1978: 63-79.

General conclusions from a number of studies indicate that farm animals and wild animals are typically startled by the first exposure to a sonic boom. The reaction is usually slight, with little effect on behavior, and most animals appear to adapt to further booms. More studies are needed on the direct effects of booms on wild animals. Sonic booms are more disturbing to birds than to mammals, and may adversely affect colonial nesters.

23. Dauphine, T. C., Jr.; McClure, R. L. Synchronous mating in Canadian barren-ground caribou. Journal of Wildlife Management. 38(1): 54-66; 1974.

Evidence indicates that synchronous conceptions are essential to successful reproduction in barren-ground caribou. Dates of mating are influenced by environmental and social factors that may be disturbed by increased levels of human activity. Migration may serve an important function in synchronous breeding. Disturbance during autumn migration may interfere with communication of mating stimuli. Physical barriers on migration routes could alter the timing and synchrony of mating by (1) confining the population to a portion of their range, causing greater variation in prerutting conditions among females, and (2) forcing migration through unfamiliar areas, which may alter the social composition of rutting bands.

24. DeForge, J. R. Stress: is it limiting bighorn? In: Desert Bighorn Council. Transactions-1976; 1976 April 7-9; Bahia Kino, Mexico. Las Vegas, NV: Desert Bighorn Council. 20: 30-31; 1976.

Bighorn sheep are very sensitive to human intrusion and may be driven from portions of their home range.

The species' social organization is such that, if habitat is lost, sheep congregate in an adjacent area, causing local overpopulation and increased stress. This triggers a behavioral-physiological self-regulatory mechanism evolved to control population growth. Sheep then experience behavioral disturbances, inhibition of reproductive functions, and decreased resistance to disease, leading ultimately to a population reduction.

25. deVos, A. Behavior of barren-ground caribou on their calving grounds. Journal of Wildlife Management. 24(3): 250-258; 1960.

The author observed the reactions of caribou to his approach. Herds generally stampeded in tight formation in response to a close approach, but ran in more loosely formed groups when less alarmed. Large bands were more easily approached. Cows with calves appeared very sensitive and often continued to flee after the rest of the herd had settled.

26. Dorrance, M. J.; Savage, P. J.; Huff, D. E. Effects of snowmobiles on white-tailed deer. Journal of Wildlife Management. 39(3): 563-569; 1975.

Data suggest that deer, which had not been hunted for several years, became habituated to snowmobiles in an area receiving heavy, weekend recreational snowmobile use. Light traffic displaced deer from areas immediately adjacent to trails. Increased traffic thereafter caused no further response. In an area where snowmobiles were generally prohibited, deer home-range size, movements, and distance to nearest trails increased with snowmobile activity.

27. Dunaway, D. J. Bighorn sheep habitat management in the Inyo National Forest—a new approach. In: Desert Bighorn Council. Transactions-1971; 1971 April 7-9; Santa Fe, NM. Las Vegas, NV: Desert Bighorn Council; 15: 18-23; 1971a.

The author suggests that the increase in human use of bighorn sheep ranges may be the major factor contributing to the decline in bighorn numbers. Though no statistically sound data are available, the relationship of presently occupied bighorn ranges to human use in the Sierra Nevada offers supporting evidence. In areas where a large increase in human use has had the greatest impact, two of five sheep ranges described in 1948 appear unoccupied; one contains half of the 1948 population. Where human use has remained low (two areas), sheep populations are static.

28. Dunaway, D. J. Human disturbance as a limiting factor of Sierra Nevada bighorn sheep. In: Transactions of the first North American wild sheep conference; 1971 April 14-15; Fort Collins, CO. Fort Collins, CO: Colorado State University, Department of Fishery and Wildlife Biology; 1971b: 165-173.

"Although difficult to prove, it appears that human disturbance may be a major factor that limits the bighorn in the Sierra." Normal limiting factors would probably not be effective in depressing a population which has decreased significantly since 1950. A threefold increase in recreational use is the only major difference in the ranges, which were previously rarely visited. The relationship between heavy human use and absence of bighorn is stressed. The author warns that continued losses may lead to eventual extinction.

29. Eberhardt, L. E.; Hanson, W. C.; Bengtson, J. L.; Garrott, R. A.; Hanson, E. E. Arctic fox home range characteristics in an oil-development area. Journal of Wildlife Management. 46(1): 183-190; 1982.

Petroleum development facilities were present in the home ranges of all radio-tracked foxes (14). Avoidance of sites with high levels of human activity varied among foxes. Resident foxes successfully raised young in natural dens within 83 ft of heavily traveled roads, and 165 ft of operating drill rigs. Foraging was common at sites where garbage and handouts were available, in years of lemming abundance as well as scarcity. Juvenile use of developed sites increased as young became more mobile in late summer. Garbage food sources may have contributed to changes in the Prudhoe Bay fox population, which was more dense and experienced less dramatic cyclic fluctuations than populations in less disturbed areas. No differences in natural habitat qualities were apparent between areas. Little or no commercial trapping occurred on the study area.

30. Eckstein, R. G.; O'Brien, T. F.; Rongstad, O. J.; Bollinger, J. G. Snowmobile effects on movements of white-tailed deer: a case study. Environmental Conservation. 6(1): 45-51; 1979.

Data showed that snowmobile activity had no significant effect on home-range size, habitat use, or daily activity patterns of white-tailed deer wintering in Wisconsin. Snowmobile activity did cause some deer to leave the immediate vicinity of the snowmobile trail. Darkness decreased the reaction to disturbance. Deer appeared to react more to a person walking than on snowmobile.

31. Elgmork, K. Human impact on a brown bear population (*Ursus arctos* L.). Biological Conservation. 13(2): 81-103; 1978.

This study looked at the effect of human activity on a remnant brown bear population in southern Norway over 25 years. Bear reports were compared with indices of human activity, primarily the building of a forest road network and clearcutting. Forest road density was used as an indicator of human impact. The number of bear observations was negatively correlated with forest road density and positively correlated with length of timberline in an area. Negative tendencies were also indicated in areas close to cabin concentrations. The author feels this effect may be more visible later, as extensive building of cabins has occurred only in the last 10 years. A theoretical model is developed—and supported by field observations—relating bear observations, timberline, and roads.

32. Ellis, D. H.; Goodwin, J. G., Jr.; Hunt, J. R. Wildlife and electric power transmission. In: Fletcher, J. L.; Busnel, R. G., eds. Effects of noise on wildlife. New York: Academic Press; 1978: 81-104.

The potential effects of powerlines and rights-of-way are described. Construction and maintenance activities may cause displacement of wildlife. Wildlife avoidance of powerline corridors has been little studied. No published studies are known on the response of wilderness species to powerlines. Collisions with wires have been documented for many species of birds. These generally involve few birds, but can be serious mortality factors in

some cases. Legal and illegal hunting increases wildlife mortality along rights-of-way and transmission line access roads, especially in previously unroaded areas. Raptors perched on utility poles are particularly vulnerable. Studies indicate that hunters concentrate along roads and cleared trails, and this has been shown to affect elk movement. Benefits of powerlines include increased food for big game along corridors and additional perches and nest sites for raptors. Research in Idaho and Montana showed that a transmission line did not make a right-of-way less attractive to deer and elk feeding in the cleared area during early spring. No significant difference in big game use of rights-of-way and control clearings was noted. Elk and deer showed no apparent hesitation in crossing the corridor.

33. Epsmark, Y. Behavior reactions of reindeer exposed to sonic booms. Journal of the British Deer Society. 2(8): 800-802; 1972.

Reindeer held in an enclosure showed moderate reactions (startle response, raising head, pricking ears) when exposed to 36 sonic booms. Panic response and extensive changes in behavior were not observed. No difference in reaction to varied boom strengths was observed. This may be explained by possible habituation, or differences in individual sensitivities. Sleeping and grazing animals appeared less startled. Effects on reproduction were not part of this study. Therefore, negative influences of sonic booms on reproduction cannot be excluded, as sensitivity may increase during this period.

34. Faro, J. B.; Eide, S. H. Management of McNeil River State Game Sanctuary for nonconsumptive use of Alaskan brown bears. Proceedings of the Western Association of State Game and Fish Commissioners. 54: 113-118; 1974.

An increase in numbers of visitors attempting to photograph bear concentrations at waterfalls on the McNeil River caused bear-human conflicts. Activity patterns and tolerance of bears changed in response to increasing human disturbance. Bears left the falls as people arrived, gradually returned as people settled, and left again as visitors departed. Heaviest use by bears occurred in the evening in the absence of humans. With light disturbance, bears tended to use the falls all day. Evidence of abandonment of the area by bears is indicated. In previous years, bears had appeared quite tolerant of infrequent human activity. As visitor numbers increased, bears entered camps more often and showed tolerance only if human activities remained within previously established patterns.

35. Geist, V. A behavioural approach to the management of wild ungulates. In: Duffey, E.; Watt, A. S., eds. The scientific management of animal and plant communities for conservation: eleventh symposium British Ecological Society. Oxford: Blackwell Scientific Publications; 1970: 413-424.

General effects of human disturbance on ungulates are described. Voluntary abandonment of available habitat, in response to disturbance, will confine a population to a smaller, often less favorable, area. This may result in detrimental physiological effects on the animals and wasted habitat. The severity of the effect depends on such factors as the social behavior of a species. Disturbance may upset the animals' energy budgets, ultimately resulting in decreased reproductive performance caused by absorption of embryos, lower birth weights, and reduced survival of young. The paper also discusses behavioral aspects of disturbance.

36. Geist, V. Bighorn sheep biology. The Wildlife Society News. 136: 61; 1971a.

"Mammals learn to minimize encounters with humans, if harassed enough, by reducing activity to areas, habitats, and times of day where encounters with humans are minimal." This can change the ecology or reduce the size of a population by habituating animals to live in "second-rate" habitats (reference 8 is cited as an example).

37. Geist, V. Is big game harassment harmful? Oilweek. 22(17): 12-13; 1971b.

Harassment of caribou is most detrimental at critical times such as late pregnancy, calving, and during very cold weather. Chasing pregnant females for long distances (by aircraft or vehicle) can cause abortion or fetus displacement. Excitement upsets the animal's hormonal system, and may adversely affect embryo growth. Severe weight loss in early gestation, which may result from harassment combined with natural stress, has been documented to cause fetus resorption in female reindeer. Disturbance of caribou at calving time can potentially result in trampling, desertion, or increased predation of young.

38. Geist, V. Behavior. In: Schmidt, J. L.; Gilbert, D. L., eds. Big game of North America: ecology and management. Harrisburg, PA: Stackpole Books; 1978: 283-296.

The principles of learning explain many responses of wildlife to human disturbance. Animals may initially react with fright to an unusual sound, but subsequent behavior depends on the experiences associated with the sound. Animals often learn to ignore persistent, localized noise (airports, industrial activity) that they can approach or avoid. They will respond with excitation and flight to sounds associated with alarming events (pursuit by vehicle) but may search for the source of sounds with positive associations (chain saw noise indicating food to deer).

Avoidance or abandonment of areas associated with unpleasant experiences, such as human disturbance, may result in a reduction in range. Predation, increased energy expenditure, and loss of access to resources may subsequently reduce the population. Highly gregarious ungulates are generally most seriously affected.

If human contacts continue to occur and are not negatively reinforced, grizzly bears will not only learn to ignore people, but will proceed to the next stage of behavior—total exploration—which must be preceded by attack.

39. Graber, D.; White, M. Management of black bears and humans in Yosemite National Park. Cal-Neva Wildlife. 1978: 42-51.

A recent increase in bear/human conflicts in Yosemite backcountry can most likely be explained by the great influx of hikers and campers during the past decade. This has increased familiarity and, subsequently, reduced fear of humans by bears whose home-ranges include backcountry camping areas.

40. Gruell, G. E.; Becker, K.; Roby, G.; Johnson, R. Gros Ventre Cooperative Elk Study - progress report. Jackson, WY: U.S. Department of Agriculture, Forest Service, Bridger-Teton National Forest and Wyoming Game and Fish Department; 1975. 127 p.

This study on the influence of logging on elk concluded that the activity, not the physical existence, of primitive roads influences elk behavior. Data indicate that four-wheel-drive roads had minimum influence on elk when used infrequently during summer. During hunting season, elk avoided areas of regularly used roads. Their movements increased and became more erratic, apparently influenced by hunter disturbance and, possibly, rutting activities.

41. Gunn, A.; Miller, F. L. Responses of Peary caribou cow-calf pairs to helicopter harassment in the Canadian high arctic. In: Reimers, E.; Gaare, E.; Skjennelberg, S., eds. Proceedings, second international reindeer/caribou symposium; 1979 September 17-21; Roros, Norway. Trondheim, Norway: Direktoratet for viltog Jerskvannsfisk; 1980: 497-507.

Cow-calf responses to helicopter passes of 790 to 1,220 ft were observed. Calves tended to be more alert, respond sooner, and initiate cow-calf regrouping more often than their maternal cows. The level of response was less in August than in July. Responses diminished as the helicopter departed. The tendency of cow-calf pairs to reunite increased the response level of other caribou. The behavior of the maternal cow apparently acted as a signal for the group to move away from the disturbance.

42. Hanley, P. T.; Hemming, J. E.; Morsell, J. W.; Morehouse, T. A.; Leask, L. E.; Harrison, G. S. Natural resource protection and petroleum development in Alaska. Report prepared for Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC. 318 p.

General impacts of petroleum development in Alaska are described. Noise may cause animals to avoid areas while activity is in progress. Land surface alteration has eliminated critical habitat, particularly nest sites of shorebirds, which have been displaced in large numbers with adverse effects on their reproductive potential. Shorebird nesting densities have been reduced as a result of the "road effect"—a combination of noise, activity, and dust ("dust shadow") that extends the area of disturbance and habitat alteration beyond the actual road. Use of cleared areas (roads, rights-of-way, etc.) may increase for some species due to the presence of preferred food, increased edge, and easier travel routes. Improper garbage handling and feeding by workers have attracted bears and other scavengers, which have subsequently shown signs of behavior alteration, including loss of fear of humans. Fuel, oil, and mud spills reduce habitat by destroying vegetation. Fuel spills are especially destructive. Water pollution is more serious than land pollution and may cause injury or death of wildlife.

43. Hanson, W. C. Caribou encounters with pipelines in northern Alaska. Canadian Field-Naturalist. 95(1): 57-62; 1981.

Caribou reactions to raised berms resulting from pipeline burial were observed. Caribou movements were deflected when berms were higher than 1.2 m; but the animals readily crossed lower berms. Bulls showed greater acceptance of the berms than did cows and calves, especially during the second study season. Caribou sensitivity to the installation appeared to decrease with increased experience. Animals often seemed reluctant to leave elevated berms when a breeze offered relief from insect harassment.

44. Harding, L.; Nagy, J. A. Responses of grizzly bears to hydrocarbon exploration on Richards Island, Northwest Territories, Canada. In: Martinka, C. J.; McArthur, K. L., eds. Bears - their biology and management. [Calgary, AB]: The Bear Biology Association; 1980: 227-280.

Observations showed that although bears coexisted with industrial activity they appeared to actively avoid drilling and staging camps. Bears entering camps fled quickly from crowds and motorized vehicles. Some bears wintered successfully in dens 1 to 4 mi from active camps. Others abandoned dens directly disturbed by seismic vehicle and gravel mining activities. Bear responses to aircraft were variable and unpredictable. Most animals responded with some degree of aversion and/or energy expenditure. Bears responded more to helicopters than to fixed-wing aircraft. Animals previously captured and tranquilized avoided subsequent aircraft approaches. Although there is no evidence to suggest that current numbers and distribution—which have apparently stabilized in relation to existing facilities—of bears are significantly affected by oil field activities, the authors feel that cumulative impacts of proposed development will reduce the current population to the point where its continued existence will depend on immigration.

45. Harms, D. R. Black bear management in Yosemite National Park. In: Martinka, C. J.; McArthur, K. L., eds. Bears - their biology and management. [Calgary, AB]: The Bear Biology Association; 1980: 203-212.

"The natural behavior, foraging habits, distribution, and numbers of black bears in Yosemite National Park have been significantly altered by habituation to human-supplied food sources." Extensive development, and high levels and patterns of visitor use, have concentrated human use in available bear habitat, increasing the potential for bear/human encounters. Repeated food-reward associations with people, in addition to a loss of fear of humans, have contributed to the bears developing increasingly sophisticated depredation patterns.

46. Harrison, R. T. Quantifying the acoustic dose when determining the effects of noise on wildlife. In: Fletcher, J. L.; Busnel, R. G., eds. Effects of noise on wildlife. New York: Academic Press; 1978: 267-285.

We have little knowledge of the threshold levels at which particular sounds are perceived by wildlife species, or how animals specifically react to a particular sound. Mere perception of certain sounds by wildlife can cause significant reactions. Often it is the information carried by the perception of the sound rather than the sound itself that causes the reaction.

Carnivores, such as grizzly bears, are a concern in areas affected by petroleum activities, and this review focuses on them.

47. Hershey, T. J.; Leege, T. A. Influences of logging on elk on summer range in northcentral Idaho. In: Hieb, S. R., ed. Proceedings, elk-logging-roads symposium. Moscow, ID: University of Idaho, Forest, Wildlife and Range Experiment Station; 1976: 78-82.

Data showed that elk avoided habitat within 0.25 mi and showed preference for areas more than 0.25 mi from primary and secondary roads. Use apparently decreased in proportion to road density, intensity, type, and use season. A long-established road open to traffic and crossing an elk use area disrupted elk within 0.25 mi by forcing them to disperse farther from the road, or causing their elimination through increased hunter access and harvest. The population studied was heavily hunted and vulnerable due to road densities and clearcuts. When undisturbed, elk began to use roads as travel lanes and areas close to roads for feeding and resting when snow depth was more than 12 inches. Elk were closest to roads in November.

48. Hicks, L. L.; Elder, J. M. Human disturbance of Sierra Nevada bighorn sheep. Journal of Wildlife Management. 43(4): 909-915; 1979.

Recreational use has apparently not decreased Mount Baxter California bighorn numbers. Overall bighorn distribution was not negatively related to human presence, and was positively related to food resources. Foot trails did not adversely affect sheep movement and were often used by the animals. Humans and bighorn were generally spatially separated on summer range due to preferences for different habitat features. Frequent contact was limited to specific areas, where sheep appear conditioned to hikers and can watch them approach from some distance below. Herd size and the distance and elevation of a person in relation to the sheep influence the sheep's reaction to human approach. Bighorn reacted more often to an approach from above than one from below. Smaller groups appeared more susceptible to disturbance. Results of this study were based on low human use (under 25 per day).

49. Hinman, R. The impact of oil development on wildlife populations in northern Alaska. Proceedings, Annual Conference of Western Association of State Game and Fish Commissioners. 54: 156-164; 1974.

A study by Child (1973) on pipeline crossing by caribou found that the majority of caribou tended to avoid simulated pipeline structures. Less than 25 percent used ramps and underpasses; the rest did not cross. The degree to which crossing facilities were used depended to some extent on the age and sex composition of the group, the degree of insect harassment, and chronology. There was some evidence that caribou might habituate to the structure with experience.

50. Hood, R. E.; Inglis, J. M. Behavioral responses of white-tailed deer to intensive ranching operations. Journal of Wildlife Management. 38(3): 488-498; 1974.

Data suggested that deer home ranges were enlarged and/or completely shifted in response to repeated cattle roundup disturbance. After initiation of roundups, all deer made frequent excursions outside their known home ranges, often independent of the timing or intensity of disturbance. Deer reaction to cattle drives varied by sex. Bucks responded more than does, generally reacting with a long flight, and ranging farther during disturbance than at other times. Does usually took a circuitous escape route, but returned within a few hours, and did not range farther during disturbance than at other times.

51. Horejsi, B. L. Behavioral response of barren-ground caribou to a moving vehicle. Arctic. 34(2): 180-185; 1981.

"In general, caribou exhibit signs of anxiety and fear when encountering a fast-moving vehicle, and they exert themselves strenuously for a short period when withdrawing from a vehicle. It appears that caribou react to a vehicle based on the rate of approach, involving the principle of looming, rather than on the movement itself." Looming is "the accelerated magnification of the form of

an approaching object." Most caribou reacted to a pickup, traveling at least 35 mi/h, by running (48 percent) or trotting (38 percent) away. Response differed by sex in forested habitat, where males allowed a much closer approach than females, but not in open habitat.

52. Interstate Oil Compact Commission. Additional environmental problems relating to oil and gas production. Oklahoma City, OK; 1974. 16 p.

In response to a survey, nine States reported wildlife deaths due to pits associated with oil field operations. Significant numbers of animals were involved in California and Colorado. The problem was continuing in three States, and of short duration or unique in the others. Five States reported specific instances of waterfowl deaths on reserve pits, especially during migration. The main causes of death included: (1) coating of birds with oil from the pit, preventing flight, and (2) ingestion of toxic substances as a result of drinking in the pits. Livestock drownings have also been reported.

53. Kennedy, K. The environmental impacts of energy extraction. Environmental Views. 2(1): 3-8; 1979.

Salt water spills, generally from injection pipelines, are relatively unpublicized, but "definitely on the rise, in contrast to the declining volume of oil spilled." Water associated with oil wells typically contains a very high concentration of salt which, when mixed with surface fresh water, can make it undrinkable. On land, the salts can kill plants.

54. Klein, D. R. Reaction of reindeer to obstructions and disturbances. Science. 173: 393-398; 1971.

Well-traveled highways and railroads have obstructed movements of wild reindeer in Scandinavia and caused them to abandon a portion of their range. Reindeer stopped crossing railroad tracks, which transected their range, when train traffic increased several years after construction of the tracks. The animals have apparently become somewhat habituated to normal amounts of highway traffic. However, vehicle collisions kill many animals each year, especially in winter, when reindeer use roads and railroads as snow-free travel routes. Evidence suggests that reindeer (wild and domesticated) in poor physical condition are less able to adjust to environmental disruptions than animals in good physical condition. The author believes that "the Scandinavian experiences with reindeer should provide a basis for anticipating the problems to be encountered with caribou."

55. Klein, D. R. The impact of oil development in the northern environment. Petrolieri d'Italia. 1972 October: 39-44.

Obstruction of seasonal migrations of large mammals reduces efficiency of habitat utilization, and may isolate essential range components, causing a reduction in animal numbers. Wildlife displaced as a result of human disturbance cannot be expected to find suitable, unoccupied habitat to support them in adjacent areas, but will potentially die of natural causes or displace other animals. We must assume that a balance already exists between the habitat and resident animals in areas adjacent to disturbance.

The Rocky Mountain area, including bighorn sheep range, has received considerable emphasis in wildlife-petroleum research, especially in recent years.

56. Klein, D. R. The reaction of some northern mammals to aircraft disturbance. In: Eleventh International Congress of Game Biologists; 1973 September 3-7; Stockholm, Sweden. Stockholm, Sweden: National Swedish Environmental Protection Board; 1974: 377-383.

Caribou generally showed stronger and/or more frequent reactions: (1) to helicopters than fixed-wing aircraft at low altitudes; (2) when aircraft altitude was 200 ft or less (strong flight and panic responses); (3) during summer rather than spring migration, except during periods of severe insect harassment, when reactions decreased; and (4) in larger groups (more than 10), especially cow-calf-yearling groups. Caribou often changed their activity or altered their behavior in response to aircraft. Moose showed greater indifference to aircraft, though cows and calves often ran. Wolves appeared least disturbed and showed evidence of habituation. Grizzly bears reacted very strongly, running and attempting to avoid the aircraft. The previous experience of wildlife with aircraft may be an important consideration in Alaskan and Canadian studies.

57. Klein, D. R. The Alaska oil pipeline in retrospect. Transactions of the North American Wildlife and Natural Resources Conference. 44: 235-246; 1979.

Caribou have not adjusted as well as moose to the presence of the trans-Alaska pipeline. Research has shown that caribou have altered their movements and patterns of range use in relation to the pipeline corridor. Cows with calves show pronounced avoidance of the pipeline, road, and oil field. Traffic and human activity appear more directly responsible for avoidance behavior than does the physical presence of the pipeline, road, and facilities. Animals along the haul road are especially vulnerable to poaching because of the open terrain and the fact that many became tame during the peak of construction activity. Poaching, especially of furbearers, has increased as pipeline-related traffic has decreased.

58. Knight, J. E. Effect of hydrocarbon development on elk movements and distribution in northern Michigan. Ann Arbor, MI: University of Michigan; 1980. 79 p. Ph.D. dissertation.

Seismic activity significantly affected movements, but not distribution and range use, of elk. Distances moved were generally inverse to the distance from seismic activity, and represented an increase of 2 to 3.5 times normal daily movement. The movement response occurred immediately following the disturbance, and normal activity patterns were followed the day after. Bulls generally did not move as far as cows when disturbed. Data suggest that, as a result, harems may be broken up and herd organization disrupted during rut. Cows with calves moved significantly farther than cows without calves. Oil well activity did not affect movements or distribution of elk. Until elk become accustomed to noise and activity at drilling rigs, which extend the influence of drilling beyond the actual site, they may avoid parts of their range. On the other hand, noise allows animals to become aware of disturbance before it is seen, so they are not startled.

59. Kovach, S. D. An ecological survey of the White Mountain Peak bighorn. In: Desert Bighorn Council. Transactions-1979; 1979 April 4-6; Boulder City, NV. Las Vegas, NV: Desert Bighorn Council; 23: 57-61; 1979.

Observations suggested that bighorn sheep would not tolerate a direct approach, or approach from above, by humans. The critical flight distance observed for active approach to bighorns, at which they immediately left the area, appeared to be 300 to 350 ft. The animals were apparently not disturbed by people in vehicles, but fled if a person left the vehicle.

60. Kushlan, J. A. Effects of helicopters on wading bird colonies. Journal of Wildlife Management. 43(3): 756-760; 1979.

Neither fixed-wing aircraft nor helicopters flying at altitudes of at least 200 ft "drastically disturbed" egret and heron colonies. Ninety percent of the birds showed no reaction or merely looked up. Disturbance caused by helicopters was less than or equal to that caused by fixed-wing aircraft. The author cautions that the effects of aircraft surveys may differ under other conditions or with other aircraft.

61. Kvale, C. T. Preliminary phosphate mining impacts on mule deer, elk, and moose in southeastern Idaho. Proceedings, Western Association of Fish and Wildlife Agencies. 60: 527-545; 1980.

Phosphate mining activities apparently contributed to a delay in mule deer migration to winter range. Increasing snow accumulation may have added to the delay. Deer migrating through a mine site area (including roads, railroads, human activity) arrived significantly later on the winter range than those that bypassed the mine area. Forced delays in migration, with increasing snow accumulation, could cause sufficient additional stress to be detrimental to wildlife. Population dynamics may ultimately be affected. The author concludes that the number of acres removed from big game production will ultimately determine the impact of phosphate mining on ungulates.

62. Leslie, D. M., Jr.; Douglas, C. L. Human disturbance at water sources of desert bighorn sheep. Wildlife Society Bulletin. 8(4): 284-290; 1980.

Desert bighorn sheep altered their behavior and movements in response to construction activity near their primary watering hole. The percentage of sheep watering at the construction site declined significantly during construction and increased significantly at a less disturbed site. The sheep that continued to water near construction altered their direction of approach to avoid the impacted area yet maximize visual contact with the site. Assuming subpopulations at water sources are generally at summer carrying capacity, an increase in sheep numbers at one source would cause overutilization of forage. Sheep productivity was apparently not affected, but lamb survival may have been. The affected population was highly habituated to human presence. The authors conclude the observed responses would be magnified in areas where sheep were less accustomed to humans and where alternative water sources were not available.

63. Lieb, J. W.; Mossman, A. S. Final progress report on Roosevelt elk in Prairie Creek Redwoods State Park. 1967. Unpublished report submitted to California Department of Parks and Recreation, Sacramento, CA. 8 p.

Data indicate that human disturbance often caused elk to move from primary to secondary forage areas, and also disrupted rutting activities. Cows with young calves were observed to stay away from the central part of their home ranges, which received heavy human use, 3 to 6 weeks beyond normal.

64. Light, J. T. An ecological view of bighorn habitat on Mount San Antonio. In: Transactions of the first North American wild sheep conference; 1971 April 14-15; Fort Collins, CO. Fort Collins, CO: Colorado State University, Department of Fishery and Wildlife Biology; 1971: 150-157.

An analysis of bighorn sheep habitat features, habitat use, and human use indicates that heavy human use of high-value habitat is excluding bighorn use. There is evidence that large areas of bighorn habitat, suitable for occupancy, have been vacated by sheep as a result of human influence over a number of years. It appears that many documented cases of bighorn tolerance to humans occur mainly in areas where human use is relatively infrequent. Sheep may tolerate occasional human visitors, but continual human intrusion can cause stress and avoidance of disturbed areas. Observations suggest that ewes with lambs were most intolerant of humans, especially when the observer was in or above their cover element. Sheep rapidly retreated to cover when approached too closely in the open.

65. Luz, G. A.; Smith, J. B. Reactions of pronghorn antelope to helicopter overflight. Journal of the Acoustical Society of America. 59(6): 1514-1515; 1976.

Pronghorn showed no reaction to helicopter overflights of 400 ft altitude and 3,000 ft slant range. Muscle tensing and interruption of grazing were observed as the aircraft descended toward the herd. The animals ran when the helicopter was at an altitude of 150 ft and slant range of 500 ft. The pronghorn did not react to 60 dB noise, but reacted strongly to 70 dB. Helicopters are rare in the area studied. These results are in contrast to other observations of deer near a heliport apparently remaining undisturbed when a helicopter hovered 75 ft overhead.

66. Lynch, T. E.; Speake, D. W. Eastern wild turkey behavioral responses induced by sonic boom. In: Fletcher, J. L.; Busnel, R. G., eds. Effects of noise on wildlife. New York: Academic Press; 1978: 47-61.

Exposure of wild turkey brood groups and hens on nests to real and simulated sonic booms caused no apparent abnormal behavior that would reduce productivity. Alert responses lasting less than 30 seconds were generally observed.

67. Lyon, L. J. Coordinating forestry and elk management in Montana: initial recommendations. Transactions of the North American wildlife and natural resources conference. 40: 193-200; 1975.

Studies on elk (hunted population) on a Montana summer range concluded that elk moved away from logging and road construction activity until adequate security was achieved. Elk density decreased in a drainage where construction and logging occurred and increased over the ridgeline in adjacent, undisturbed drainages. Ridgeline road construction caused a reduction in density near the ridge, further movement, and changes in elk distribution for up to 4 mi. Elk reactions to even long-established, low-quality forest roads appeared to be generally negative unless adjacent timber cover was very dense. New road construction appeared to be extremely disruptive.

68. Lyon, L. J. Habitat effectiveness for elk as influenced by roads and cover. Journal of Forestry. 77(10): 658-660; 1979.

Data from 8 years of pellet counts show that western Montana elk tend to avoid habitat adjacent to open forest roads. Elk use increased with increasing distance from roads. The area avoided was inversely proportional to amount of tree cover. The author concludes that open forest roads decrease the effectiveness of available elk habitat.

69. Mackie, R. J.; Pac, D. F. Deer and subdivisions in the Bridger Mountains, Montana. Proceedings Western Association of Fish and Wildlife Agencies. 1980: 517-526.

Development of subdivisions on or adjacent to critical mule deer winter range has an important influence on deer occurrence and abundance in the Bridger Range. A reduction in the amount, quality, or availability to deer of winter range—as a result of direct habitat loss or disturbance—can be expected to decrease numbers of deer on the winter range and in areas used by those deer in summer and fall. Loss of some areas will concentrate deer in smaller areas and/or force them to use marginal habitat. Deer on adjacent, undisturbed winter ranges will probably be affected as well. Disturbance will place additional energy costs on the deer and will increase the energy deficit on which they typically exist during winter. As a result, survival and reproductive potential may be reduced the following year.

70. McMillan, J. F. Some observations on moose in Yellowstone Park. American Midland Naturalist. 52(2): 392-399; 1954.

Observations suggest that variation in moose response to human approach depends on the activity of the animal, its relation to cover, and the manner of approach. Moose appeared more tolerant of a slow, quiet approach than a fast, noisy one. Moose showed evidence of habituation to humans. Animals in relatively undisturbed areas were less tolerant of disturbance than those in areas frequented by tourists. Vehicle sounds did not seem to alarm moose in areas near roads and activity. Noise combined with movement appeared to frighten animals more than noise alone.

71. Mech, L. D. The wolves of Isle Royale. Fauna Series 7. Washington, DC: U.S. Department of the Interior, National Park Service; 1966. 210 p.

Wolves appeared conditioned to planes as low as 100 to 200 ft after several harmless encounters. Packs encountered less frequently showed more concern about the plane. Observations suggested wolves were afraid of humans. They were easily chased from a moose carcass

and did not return for several hours. Wolves appeared afraid of objects with recent human scent but not of man-made structures with no recent scent.

72. Memphis State University. Effects of noise on wildlife and other animals. 1971. Unpublished report prepared for U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, DC. 74 p.

Literature dealing directly with the effects of noise on wildlife is limited. Effects can be inferred from lab studies on domestic animals, incidental observations of wildlife response to noise, and information on communication and auditory ranges of different species. Suspected effects of noise on wildlife include (1) masking of signals that influence courtship, spacing, care of young, prey detection and escape, etc., and consequent interference with these life processes, and (2) direct effects on physiological and behavioral processes, including hearing loss and noise-induced stress responses. A lack of visible response by an animal does not necessarily imply adaptation or lack of effect.

73. Michael, E. D. Effects of highway construction on game animals. Proceedings Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 32: 48-52; 1978.

Populations of white-tailed deer, rabbit, ruffed grouse, gray squirrel, and turkey were apparently not affected by road construction (using heavy equipment and blasting). The amount of animal sign near the highway did not differ significantly from the amount 1 mi away for any species. For these species, habitat loss is restricted to the area occupied by pavement, berm, and right-of-way. The addition of right-of-way vegetation and creation of ecotonal areas will cause some wildlife species to increase, while others decrease.

74. Milke, G. Animal feeding: problems and solutions. Special Report No. 14. Anchorage, AK: Joint State/Federal Fish and Wildlife Advisory Team; 1977. 11 p.

Animal feeding was a major problem during construction of the Alaska pipeline and is continuing into the operations and maintenance phase to a lesser extent. Large numbers of animals—especially bears, wolves, foxes, ground squirrels, gulls, and ravens—were attracted to human activity as a result of active feeding by employees and improper handling and disposal of food and garbage. The actual and potential adverse effects of animal feeding include: (1) alteration of normal behavior and/or nutrition, which may be passed on to subsequent generations; (2) loss of fear of humans, which may lead to human injury or property damage; (3) destruction and/or harassment of "nuisance" animals; (4) vehicle collisions with, or illegal shooting of, animals waiting along road for "handouts" (commonly given by truckers); (5) delay of traditional movements by animals which stay near camps to be fed. These may interfere with normal denning of bears, and nutrition of wolves, which normally follow caribou.

75. Miller, F. L. A new era—are migratory barren-ground caribou and petroleum exploitation compatible? Transactions of the Northeastern Section, The Wildlife Society. 31: 45-55; 1974.

Results of intensive study indicate that the primary factor limiting growth of the Kaminuriak caribou population was a low rate of annual increment due to high losses of calves during the first month of life. The strong affinity of females for calving and postcalving areas increases the vulnerability of calves to human disturbance. Patterns of activity during and after calving may be necessary for maintaining the social structure and discreteness of the population. Pipeline construction near calving and summering areas may threaten socialization, causing abandonment of traditional ranges, greater calf mortality, and reduction of the population. The cow-calf bond may be weakened if arrival on the calving ground is delayed, or the energy cost of travel is raised, due to the presence of barriers on the migration route. Calf survival would most likely decrease because bonding minimizes the possibility of permanent cow-calf separation during the critical time following birth.

76. Miller, F. L.; Gunn, A. Responses of Peary caribou and muskoxen to helicopter harassment. Occasional Paper No. 40. Ottawa, ON: Canadian Wildlife Service; 1979. 90 p.

Responses of caribou and muskoxen to helicopter overflights simulating activities associated with construction of an arctic gas pipeline were intensively observed and analyzed. The results indicate that (1) "the responsiveness of cows and calves of both species and solitary bull muskoxen, (2) group size and type, (3) number of calves in a group, (4) the position of the sun and direction of the wind relative to the helicopter flight, (5) previous activity of the animals, and (6) the terrain" were factors contributing to the level of response. An inverse relationship was exhibited between response level and helicopter altitude or distance from helicopter landing. Cows and calves tended to be more responsive than other sex/age groups. Overt responses (movement in response to the stimulus, defense formations, alert response) were observed for 64 percent of the caribou samples and 44 percent of the muskox samples. Ground activities by people after landings seemed to influence subsequent responses more than did the presence of the helicopter. Circling overflights caused greater responses than other types of flights. Habituation was evident within, but not between, sets of passes simulating cargo-slinging. Visible pathological conditions, group splintering, and calf desertion were not observed. The energy costs of responses, and their consequences for the population, are not known.

77. Miller, F. L.; Gunn, A. Behavioral responses of muskox herds to simulation of cargo slinging by helicopter, Northwest Territories. Canadian Field-Naturalist. 94(1): 52-60; 1980.

The investigators observed muskox responses to sets of overflights of five to six passes each. During the second year of study, a trend toward decreasing responsiveness within sets of passes was evident, indicating short-term habituation. Muskoxen tended to canter, gallop, or form group defense formations more often during the first three passes. They remained bedded or foraging, walked away, or became alert more often during the last three passes of each set. One herd showed some evidence of long-term habituation; but two herds showed greater

responsiveness with time, apparently due to rutting activity. The animals' previous experience, stability of the social order, and recent exposure to wolf attack may contribute to variations in response. There was no evidence of injury, herd splintering, or range abandonment.

78. Miller, F. L.; Jonkel, C. J.; Tessier, G. D. Group cohesion and leadership response by barren-ground caribou to man-made barriers. Arctic. 25(3): 193-202; 1972.

An attempt to corral migrating caribou with a man-made barrier failed because the animals would not leave the frozen water course at the corral entrance nor deviate from learned travel routes. Some caribou were delayed by attempts to circumvent the barrier. Others overcame it and continued on their course. Energy expenditures were increased for caribou forced to crawl under or jump over the fence. Any disruption of caribou movement could be detrimental to cow and calf survival.

79. Morgantini, L. E.; Hudson, R. J. Human disturbance and habitat selection in elk. In: Boyce, M. S.; Hayden-Wing, L. D., eds. North American elk: ecology, behavior and management. Laramie, WY: University of Wyoming; 1979: 132-139.

Data on wintering elk in Alberta indicate that elk habitat selection in winter may be determined by human activity and not simply a response to thermal environment. The habitat selected was not related to weather conditions, but was strongly related to time of day and proximity to roads. Daily activity patterns were influenced by roads. Extensive use and overgrazing of marginal sectors of potentially available grassland was evident in an area crossed by a road system. This use pattern may have been related to a special winter hunt resulting in heavy harvest for 6 years prior to the study. During the hunt, distribution and habitat use changed significantly. Elk abandoned the grassland and moved to open mountain slopes.

80. Newman, J. R.; Brennan, W. H.; Smith, L. M. Twelve-year changes in nesting patterns of bald eagles on San Juan Island, Wash. Murrelet. 58(2): 37-39; 1977.

Although human activity in areas near bald eagle nests has increased significantly since 1962-63, nest surveys show that numbers of nests and occupied nests have also increased significantly. Most nests are much closer to roads and buildings now than in 1963. Near the greatest concentration of buildings alternate nests are associated with occupied nests, representing a change in nesting pattern. No productivity data were obtained.

81. Owens, N. W. Responses of wintering brent geese to human disturbance. Wildfowl. 28: 5-14; 1977.

Disturbance reduced feeding time (3 to 5 percent) and increased time spent in flight for wintering brant geese (*Branta bernicla bernicla*). Brant were very sensitive to aircraft disturbance, especially any plane below 1,650 ft and up to 1 mi away; slow, noisy aircraft—helicopters—"caused widespread panic." The geese also reacted to large birds with a slow wingbeat. Brant showed little reaction to nearby loud, but regular, sounds (weapon testing) after the first weeks. They flushed in response to unexpected sounds—nearby gunshots. Geese usually left the area when severely disturbed by people on the ground; however, they showed evidence of partial habituation to humans. When disturbances occurred very frequently, the geese appeared to become more easily disturbed with each subsequent disturbance. The birds were more easily disturbed when feeding in unfamiliar areas or areas associated with danger (hunting). Availability of alternate feeding areas appeared to influence avoidance of disturbed areas and areas with poor visibility. The author concludes that "disturbance would be harmful if it consistently resulted in birds losing more energy (through extra flying and lost feeding time) than they were able to make up by food intake" during undisturbed periods.

Waterfowl, and the impacts of activities associated with petroleum exploration and development, have been studied in some depth, which is reflected in this review.

82. Pedersen, R. J. Management and impacts of roads in relation to elk populations. In: Ittner, R.; Potter, D. R.; Agee, J. K.; Anschell, S., eds. Recreational impact on wildlands: conference proceedings; 1979 October 27-29; Seattle, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, and U.S. Department of the Interior, National Park Service; 1979: 169-173.

During road construction, elk use declined adjacent to the disturbed area for 4,950 ft. Elk moved 825 ft to 2.5 mi from logging and road construction. Main roads caused the greatest, and primitive roads the least, reduction in elk use within 0.5 mi. Road density, location, use intensity, class, and season of use—independently or in combination—may constitute significant disturbance factors affecting elk. Roads ". . . affect elk populations directly by removing elk habitat from production, and indirectly by inducing a disturbance factor . . . which displaces elk from habitat adjacent to roads." Recreational visits occur "almost spontaneously" with access development.

83. Perry, C.; Overly, R. Impact of roads on big game distribution in portions of the Blue Mountains of Washington. In: Hieb, S. R., ed. Proceedings, elk-logging-roads symposium. Moscow, ID: University of Idaho, Forestry, Wildlife and Range Experiment Station; 1976: 62-68.

All roads through meadows and open forests significantly reduced elk use of adjacent habitat, especially on west- and south-facing slopes from 0.12 to 0.5 mi away. Limited data suggest that roads had little influence on elk use of adjacent habitat in dense forest. Roads on east slopes caused only minimum disruption of use. It appears that areas used most intensively by elk sustained the most reduction in use due to roads. Main and secondary roads on west and south slopes caused a significant decrease in deer use of adjacent meadows for 0.12 to 0.5 mi. Otherwise, the influence of roads on deer was variable and not significant.

84. Richens, V. B.; Lavigne, G. R. Response of white-tailed deer to snowmobiles and snowmobile trails in Maine. Canadian Field-Naturalist. 92(4): 334-344; 1978.

White-tailed deer response to snowmobiles seemed dependent on the deer's apparent security. Animals in the open or in hardwood stands tended to run when approached by snowmobile. Deer in softwood stands, which provided more cover, showed a greater tendency to stay when approached. A significantly greater number of deer ran from a person walking than from a person on snowmobile.

85. Rost, G. R. Response of deer and elk to roads. Fort Collins, CO: Colorado State University; 1976. 51 p. M.S. thesis.

Refer to 86.

86. Rost, G. R.; Bailey, J. A. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management. 43(3): 634-641; 1979.

Data from fecal pellet counts indicate that deer and elk avoid roads, especially areas within 660 ft. Road avoidance was greater (1) east than west of the Continental Divide, (2) along more heavily traveled roads (trends only), (3) by deer compared to elk, (4) for deer in shrub habitat compared to pine and juniper, and (5) in the species' primary winter habitat. The greater avoidance on the east side may reflect a greater availability of habitat away from roads due to lower snow accumulation. Data suggest that ungulates "may utilize areas near roads when hunger is sufficient to overcome fear." "Deer west of the Divide avoided roads, at least on some sites, even though snow accumulation presumably restricted their available habitat." Factors affecting the reactions of ungulates to roads and road-associated disturbance may be very complex and may include the species involved, the age and type of road, traffic density, road-associated construction, distance from road, vegetative type, season, whether the population is hunted, and whether the road is located in an abundant or scarce habitat type. The effects of roads on individual welfare and herd productivity are not clear.

87. Schallenberger, A. Review of oil and gas exploitation impacts on grizzly bears. Bear Biology Association Conference Series. 3: 271-276; 1980.

Raptors, or birds of prey, are one of the species groups emphasized in the literature related to animal disturbance and in this review.

The author concludes that "available information indicates that impacts of oil and gas exploitation should be considered primarily detrimental for grizzly bears in northwestern Montana." Research has shown that grizzlies tend to react strongly to aircraft, especially helicopters. Marked animals previously captured by aircraft show the greatest reaction. Helicopter disturbance may cause den abandonment. Biologists suggest that road development has contributed to a decline in numbers of bears by accelerating habitat loss and increasing hunting and poaching pressure. Use of river valleys for transportation corridors, campsites, and other activities magnifies the effect of human presence ". . . by concentrating it in some of the most vulnerable and essential grizzly habitat." Bear-human conflicts may increase as a result of secondary developments such as recreation, logging, livestock grazing, and construction of subdivisions.

88. Schultz, R. D.; Bailey, J. A. Responses of national park elk to human activity. Journal of Wildlife Management. 42(1): 91-100; 1978.

This study found no statistical evidence that heavy tourist activity or planned disturbance affect elk distribution, courtship behavior, movement patterns, or use of areas near roads. Elk generally accepted human activity and have apparently adapted to present levels of human disturbance. The authors suggest this is a learned response of unhunted elk. There was evidence, though not statistically significant, that elk avoided roads in early winter when forage was plentiful. The animals were apparently not disturbed by passing cars, but generally fled if a car slowed and prepared to stop. Elk reacted more to an approaching person than an approaching car. Elk-watching from parking lots and roads did not seem to significantly affect the animals' movements. People leaving the road caused elk to flee and caused disorganization of harems.

89. Simpson, S. G.; Hogan, M. E.; Derksen, D. V. Activity budgets and disturbance of molting Pacific brant in arctic Alaska. n.d. Unpublished paper on file at: U.S. Fish and Wildlife Service, 1011 East Tudor, Anchorage, AK.

Molting brant geese responded to aircraft, gunshots, and approaches by caribou and fox. Brant spent 3 percent of the time observed in disrupted activity, responding to disturbance. Brant responses included entering a nearby lake (44 percent), moving to the shoreline (21 percent), or no movement (21 percent). Mean duration of response was 5 minutes. There was no significant difference between duration of response to fixed-wing aircraft and helicopter. The proportion of "no response" to planes was greater than that for helicopters. Caribou and arctic fox caused large flocks of geese to move to the lake or shoreline. Birds appeared to become more sensitive to successive disturbances when disturbances were closely spaced.

90. Singer, F. J. Behavior of mountain goats, elk, and other wildlife in relation to U.S. Highway 2, Glacier National Park. 1975. Report prepared for Federal Highway Administration and Glacier National Park, West Glacier, MT. 96 p.

Mountain goats using a mineral lick were exposed to human activity along a highway that traversed their travelway, at a park exhibit near the lick, and by a nearby railroad. Goats reacted with avoidance and/or flight to all close interactions with humans. Animals at the lick showed evidence of habituation to noise from visitors at the exhibit and noise from trains. They continued to react to the sound and presence of vehicles and to loud and/or sudden nearby disturbances. A high level of disturbance by traffic and visitors was indicated by the behavior of goats crossing the highway. They responded by hesitating, fleeing, altering their crossing route, and/or delaying the crossing attempt. Unsuccessful crossing attempts occurred when goats were leaving the lick (42 percent of total attempts) and were significantly associated with the presence of visitors or heavy traffic.

Large groups, especially led by females with young, were most successful. Successful crossings were also associated with a twilight pattern of crossing that developed in response to disturbance. Goats used conifer cover when disturbed. Several goat-vehicle collisions, and many near-collisions, were observed. In several cases, females were separated from their young—one maybe permanently—by passing vehicles. Elk highway crossings were mainly twilight and nocturnal. Their routes were through conifer stands. Wintering elk were habituated to the highway and were very susceptible to poaching. Elk flight reactions were significantly correlated with location, and were greatest within 328 ft of the highway and in the backcountry.

91. Singer, F. J.; Bratton, S. P. Black bear/human conflicts in the Great Smoky Mountains National Park. In: Martinka, C. J.; McArthur, K. L., eds. Bears - their biology and management. [Calgary, AB]: The Bear Biology Association; 1980: 137-139.

The occurrence of black bear damage incidents in the park was associated with the number of visitor-nights at the campsite. Between 1963 and 1975, backcountry camping increased 250 percent. After 1973, damage incidents became more common in backcountry than front country. Food storage was a contributing factor in many incidents of property damage. Between 1964 and 1976, 71 percent of bear-caused personal injuries occurred along park roads receiving the heaviest traffic. Thirty-two cases involved people feeding bears.

92. Smith, R. K. Guest editorial: energy and the environment: planning for coexistence. Overthrust News. Overthrust Industrial Association, Denver, CO; 1981; 3: 11.

Although wildlife may range over large areas during much of the year, most species congregate on small areas that are critical to survival at some time during their life cycle (breeding areas, big game winter range, sage grouse lek). If development destroys the critical area, the entire population may be eliminated. Planning development for minimal impact on critical areas should reduce the adverse effects on a population.

93. Stahlecker, D. W. Effect of a new transmission line on wintering prairie raptors. Condor. 80(4): 444-446; 1978.

Wintering prairie raptors were counted along a right-of-way in Colorado before and after construction of a transmission line. Although utility towers constituted 1.5 percent available perches, 81 percent of all perched raptors were seen on them. Raptor distribution changed significantly after transmission line construction, as bird density was greatest 0.25 mi from the right-of-way. No density difference was apparent before construction.

94. Stalmaster, M. V.; Newman, J. R. Behavioral responses of wintering bald eagles to human activity. Journal of Wildlife Management. 42(3): 506-513; 1978.

Bald eagle tolerance of disturbance was determined by analyzing eagle distribution in relation to human activity and by measuring flight distances of eagles from simulated human disturbance. Eagle distribution and daily activity patterns were changed in response to human presence. Eagles were displaced to areas of lower human activity, preventing effective use of all feeding sites and forcing more birds to use marginal habitat and a smaller area. Feeding birds were disturbed by the mere presence of humans and generally did not return to the site of disturbance for several hours. Sensitivity to disturbance increased with age. Flight distances for adults were significantly greater than for juveniles. Young birds seemed to react more to adult flight behavior than to the human intruder and may in this way become sensitized to human activity. Flight distances were shorter in heavy vegetation than in open areas. Eagles showed evidence of habituation to routine human activities and noise. They were most tolerant when the source of noise was concealed from view. Gunshots caused overt escape behavior. Nonroutine activity on the river channel was most disturbing.

95. Stuart, R. W. Surface mining and wildlife. North Dakota Outdoors. 37(5): 2-7; 1974.

"Game departments in the northern Great Plains have been aware of the fact that accelerated prospecting and development of new oil fields during the past two decades has had an adverse impact on big game populations in

the area of activities." This has resulted primarily from the building of well-maintained roads into previously inaccessible areas, which has increased pressure from legal hunting and poaching by work crews.

96. Swenson, J. E. Factors affecting status and reproduction of ospreys in Yellowstone National Park. Journal of Wildlife Management. 43(3): 595-601; 1979.

Human presence was thought to be a major factor contributing to low reproductive success, primarily due to low egg hatchability, of osprey nests on Yellowstone Lake. Success and productivity of nests on the lake were significantly lower than those of nests along streams, which were less disturbed, and of nests beyond 0.6 mi from campsites on the lake. The reproductive success of nests was increased by closing backcountry campsites within 0.6 mi of active nests. Shoreline use had a greater adverse effect on reproduction than boating did. The author suggests that the critical disturbance probably occurred during incubation. Shoreline human use may have contributed also to a loss of nests, between 1924 and 1974, from heavily used areas of the lake shoreline.

97. Tacha, T. C.; Martin, D. C.; Endicott, C. G. Mortality of sandhill cranes associated with utility highlines in Texas. In: Proceedings 1978 crane workshop; 1978 December 6-8; Rockport, TX. Fort Collins, CO: Colorado State University; 1979: 175-176.

Fifty-two sandhill cranes were found dead or dying from collisions with high voltage transmission lines and telephone lines. The collisions occurred when the birds attempted to return to their roost while fog was present. Others have noted large numbers of cranes dying from apparent collisions with utility lines during blizzards and dust storms.

98. Thomson, B. R. Reindeer disturbance. Journal of the British Deer Society. 2(8): 882; 1972.

Two years of observations in Norway determined that half of all stimuli to which reindeer reacted with alarm were human caused (hikers, hunters, snowmobiles, aircraft). The reindeer progressed in response from alert to alarm to flight, depending on the strength of the stimulus and the season. The animals were most responsive during winter and calving. Human scent, moving objects, and strange and/or sudden noises were especially alarming. Reindeer showed signs of habituation after repeated exposure to alarming sounds, but not human scent. Disturbance from loud noise was intensified if the alarming object was visible. Aircraft were very disturbing to the reindeer, interrupting activity and causing flight and panic responses. Natural predators also caused alarm and flight behavior.

99. Titus, J. R.; VanDruff, L. W. Response of the common loon to recreational pressure in the Boundary Waters Canoe Area, northeastern Minnesota. Wildlife Monograph 79; 1981. 59 p.

Data indicate that heavy recreational use had little or no effect on overall loon productivity. In the last 25 years, the adult loon population has increased 35 percent, despite an 800 to 900 percent increase in recreational use. Undisturbed loon pairs, and those habituating to human presence, seem to compensate for the slight reduction in nesting and brood-rearing success of individual pairs in areas of high human impact. Hatching success was significantly greater on smaller (generally remote) lakes, on no-motor lakes, and for less visible nests. Loon pairs on smaller lakes (trends only), on no-motor lakes, and with few human contacts showed greater success in brood rearing. Breeding pairs on remote, isolated lakes generally responded to human intrusion with more activity and excitement than those on more heavily used lakes. The behavior of loons conditioned to human use drew less attention to the nest site, expended less energy, and generally resulted in greater reproductive success. Factors which generally increased the tendency to flush and flushing distance include human approach (1) within the bird's line of vision, (2) with exaggerated or erratic movements and/or noise, and (3) early in the incubation period.

100. Tracy, D. M. Reactions of wildlife to human activity along Mount McKinley Park road. Fairbanks, AK: University of Alaska; 1977. 260 p. M.S. thesis.

Reactions of caribou, moose, Dall sheep, brown bears, red foxes, hares, and porcupines to traffic (buses) and human activity were observed. Avoidance was found only for some bears and foxes, possibly large bands of migrating caribou, and a few sensitive individuals of other species. Adult male foxes were often easily disturbed. Many individual animals appeared habituated to human activity. Responses of individual bears and wolves were highly variable, and included habituation, flight, and displacement of wolves from a den close to the road. Observations indicated that wolves could successfully den near the road if not approached by humans. Bears in the backcountry were observed to run several miles in response to human scent. Disturbances interrupted activity, decreased feeding, and increased movements by caribou within 660 ft of the road. Consequently, some areas near the road may be removed from effective habitat. Singles and small bands of caribou frequently crossed the road but showed caution in doing so, even in the absence of vehicles. The road occasionally diverted the direction of movement of caribou which used it for travel. Large migrating herds moved parallel to the road without crossing it. Disturbances thwarted some road crossings by migrating sheep but did not cause large-scale range abandonment. Some sheep crossed even in the presence of vehicles and people. Female ungulates with young were most easily disturbed. Many animals were attracted to the road. Porcupines and hares fed on new vegetation by the road in early summer but ran away from buses. They were rarely seen as food became more available in other areas. All species showed 40 percent "no visible response" between 165 and 330 ft from the road. Few visible responses were exhibited beyond 1,300 ft. Loud noises or people out of vehicles increased response strength for most species. Stopping vehicles disturbed foxes and sheep.

101. Tremblay, J.; Ellison, L. N. Effects of human disturbance on breeding of black-crowned night-herons. Auk. 96(2): 364-369; 1979.

"Visits to black-crowned night-heron colonies just before or during laying provoked abandonment of newly

constructed nests and either predation of eggs or abandonment of eggs followed by predation. Investigator disturbance caused mortality of young in some situations. Frequent disturbance also discouraged the settlement of late-nesting night-herons . . . .Clutch size and fledging success of successful early nests were the same in frequently and infrequently disturbed colonies."

102. U.S. Department of Agriculture, Forest Service. Oil and gas lease applications on the Los Padres National Forest - draft environmental assessment. Goleta, CA: U.S. Department of Agriculture, Forest Service, Los Padres National Forest; 1981. 332 p.

The two greatest factors influencing the degree of decline in use of foraging habitat may be extensive area use by human activity and the presence of large, noisy equipment. Individuals of even intolerant species occasionally show "curiosity" and tolerance when feeding near quiet, stationary equipment. Aquatic habitat may be altered by siltation, which hinders productivity and population growth of aquatic organisms, and consequently decreases food availability for some species of wildlife.

103. U.S. Department of the Interior, Bureau of Land Management. Alaska natural gas transportation system - final environmental impact statement. Washington, DC: U.S. Department of the Interior, Bureau of Land Management; 1976a. 825 p. (pp. 322-329).

Studies on the effects of gas compressor noise simulations on wildlife determined that caribou, Dall sheep, and snow geese abandoned, or reduced their use of, areas within varying distances of compressor station simulators. Degree of avoidance by caribou varied with season. All species also diverted movements to avoid the source of noise. Geese appeared especially sensitive. Geese forced to detour around compressor stations near staging areas may not be able to compensate for the increased energy expenditure and may consequently migrate with insufficient reserves. Studies on impacts of aircraft disturbance on wildlife determined the following: (1) Dall sheep reactions to aircraft were relatively severe, including panic running, temporary desertion and/or reduced use of traditional areas following activities involving aircraft and generator noise, and flight in response to aircraft at relatively high altitudes. (2) Caribou, moose, grizzly bears, wolves, raptors, and waterfowl showed variable degrees of flight, interruption of activity, and panic. Degree of response was influenced by aircraft altitude, distance, and type of flight (low circling); group size; activity of animals; sex; season; and terrain. (3) Muskoxen may have shifted their traditional summer range by 16 mi in response to heavy helicopter traffic. (4) Waterfowl, shorebirds, and bald eagles exhibited reduced nesting success and production of young, nest abandonment, and loss of eggs in response to aircraft disturbance, especially by helicopters. The addition of on-the-ground human disturbance may increase the severity of impacts. (5) Muskoxen and Canada geese near airfields appeared habituated to aircraft. Waterfowl may adapt to float planes. Wolves apparently adapt regularly to aircraft noise if not subjected to aerial hunting.

104. U.S. Department of the Interior, Bureau of Land Management. Alaska natural gas transportation system - final environmental impact statement - Canada. Washington, DC: U.S. Department of the Interior. Bureau of Land Management; 1976b. 825 p. (pp. 501, 504).

Studies found that Dall sheep interrupted activities in response to blasting 3.5 mi away, though their reactions decreased over time. Waterfowl with young avoided drilling rigs within a 2.66 mi radius. Data show that peregrine falcons deserted nests in response to construction activity. Falcons may accommodate to construction noise, except blasting, if it is not centered near the nest. Caribou can apparently tolerate winter blasting if they are not hunted.

105. U.S. Department of the Interior, Bureau of Land Management. Alaska natural gas transportation system - final environmental impact statement - overview. Washington, DC: U.S. Department of the Interior, Bureau of Land Management; 1976c. 249 p. (p. 154).

Snow geese are especially sensitive to aircraft disturbance. Geese staging for fall migration have been observed to flush up to 9 mi from low-flying aircraft. Resting geese were disturbed by aircraft at 10,000 ft. Repeated disturbance may limit energy storage necessary for migration.

106. U.S. Department of the Interior, Bureau of Land Management. Kemmerer Resource Area oil and gas leasing environmental assessment record. Rock Springs, WY: U.S. Department of the Interior, Bureau of Land Management, Rock Springs District; 1979. 191 p.

Large predators may be severely affected by development activities due to their secretive nature and tendency to avoid humans. Oil field operations may force them to leave areas of disturbance. If alternative habitat is unavailable, their population would eventually decline to a level that could be supported by the remaining available habitat. Better access into remote areas will result in a "cumulative and continual" increase in numbers of road kills, as well as a greater incidence of illegal shooting, especially of raptors. Surface disturbance of watersheds may create impacts that severely reduce aquatic life downstream. Accidents involving toxic amounts of hydrogen sulfide, though unlikely, could be lethal for wildlife, especially in low areas. Evaporation and mud pits are serious hazards for waterfowl that may land in them.

107. U.S. Department of the Interior, Bureau of Land Management. Final environmental assessment: oil and gas leasing in the Roswell District, B.L.M. Roswell, NM: U.S. Department of the Interior, Bureau of Land Management, Roswell District; 1981. 149 p.

Noise from oil field operations interferes with "booming" by male prairie chickens during courtship. Development activities on the booming grounds may force birds to abandon the area. Human intrusion often prevents pronghorn from occupying an area. This would be serious if it curtailed the use of areas in which pronghorn congregate at critical times, namely areas of dependable forb production. Hydrogen sulfide gas is known to cause

wildlife mortalities, but the extent of the problem is unknown. Brine evaporation pits, containing concentrated salts and oil films, cause "thousands of wildlife deaths, particularly birds, annually" (pp. 4-19).

108. U.S. Department of the Interior, Bureau of Land Management, and U.S. Department of Energy, Energy Regulatory Commission. Rocky Mountain pipeline project - draft environmental impact statement. Washington, DC: U.S. Department of the Interior, Bureau of Land Management and U.S. Department of Energy, Federal Energy Regulatory Commission; 1981. 305 p.

The impacts of pipeline construction on Gambel's quail would be significant if construction occurred, during the dry period, within 2 mi of gallinaceous guzzlers in nesting habitat. Disturbance could cause nest abandonment and a consequent reduction in reproductive success. Human activity may interfere with sage grouse courtship if males on leks are disturbed. Slow leaking of natural gas from the pipeline would destroy all vegetation in the area of the leak; but no direct impact to wildlife is expected.

109. U.S. Geological Survey. An environmental evaluation of potential petroleum development on the National Petroleum Reserve in Alaska. Washington, DC: U.S. Department of the Interior, U.S. Geological Survey; 1979. 238 p.

Dust from construction and/or traffic on gravel roads during early spring may cause early snowmelt and early greening of roadside vegetation. Animals tend to be attracted to roadsides until other food becomes available, thereby increasing the chances of wildlife-vehicle collisions.

110. van der Zande, A. N.; ter Keurs, W. J.; van der Weijden, W. J. The impact of roads on the densities of four bird species in an open field habitat: evidence of a long distance effect. Biological Conservation. 18(4): 299-321; 1980.

Data were collected on densities of breeding lapwings, godwits, oystercatchers, and redshanks at increasing distances from roads in an open field area of the Netherlands. Data indicated a direct relationship between population densities and distance from the road, except for oystercatchers. Oystercatcher densities decreased with increasing distance from the road. Disturbance intensity—the total population density loss over the whole disturbance distance—varied from 30 to 65 percent of the potential maximum density. Disturbance appeared to increase with traffic volume.

111. Ward, A. L. Elk behavior in relation to multiple uses on the Medicine Bow National Forest. Proceedings Western Association of State Game and Fish Commissioners. 43: 125-141; 1973.

Four-strand barbed wire fences had little influence on elk movement, though cows and calves were temporarily separated in some cases. Data show that an interstate highway (I-80) acted as a definite barrier to elk movement. Elk preferred to stay 300 yd from I-80 traffic, and from moving vehicles on logging roads. Logging roads did not act as a barrier when no traffic was present. Elk were frequently seen within 100 yd of recreational traffic on improved forest roads, especially when screened by conifers. Elk spent little time feeding in noisy areas near I-80 (62 dB for cars, 70 dB for trucks), but did not react to the noise when feeding. They quit feeding in response to a stopped vehicle and moved to cover if people approached. Elk apparently preferred to stay at least 0.5 mi from people out of vehicles—recreationists, logging crews. During timber harvest operations, elk moved from the area near the activity but were less affected in areas farther from the harvest and separated from it by a stand of conifers. A construction crew working on I-80 for 2 months did not cause elk to leave their range.

112. Ward, A. L. Elk behavior in relation to timber harvest operations and traffic on the Medicine Bow range in southcentral Wyoming. In: Hiebs, S. R., ed. Proceedings, elk-logging-roads symposium. Moscow, ID: University of Idaho, Forestry, Wildlife and Range Experiment Station; 1976: 32—43.

Traffic on forest roads had little effect on elk activity, especially beyond 0.25 mi. Elk road crossings occurred most frequently where desirable feeding sites were near the road. Timber harvest operations had a definite effect on elk distribution. The impact was less severe in areas where harvest operations were separated by 1.5 mi and activity was concentrated within one clearcut at a time. Elk use, however, was excluded from approximately 25 mi^2 during high-intensity and widely scattered timber operations in open areas with greater visibility.

113. Ward, A. L.; Cupal, J. J.; Lea, A. L.; Oakley, C. A.; Weeks, R. W. Elk behavior in relation to cattle grazing, forest recreation, and traffic. Transactions of the North American Wildlife and Natural Resources Conference. 38: 327-337; 1973.

Refer to 111.

114. Wehausen, J. D.; Hicks, L. L.; Garber, D. P.; Elder, J. Bighorn sheep management in the Sierra Nevada. In: Desert Bighorn Council, Transactions-1977; [Dates of meeting unknown]; Las Cruces, NM. Las Vegas, NV: Desert Bighorn Council; 21: 30-31; 1977.

Sierra Nevada bighorn ewe-lamb groups were studied in relation to human activity to test Dunaway's hypothesis that human disturbance was causing the disappearance of herds. Research showed that bighorn activity patterns were clearly influenced—though not severely—by frequent encounters with hikers. No permanent spatial displacement was evident and the population was increasing. The sheep reacted most strongly to humans approaching from above. The authors discourage extrapolation of results to other situations, including that of substantially greater human use of the study area. They also question the correlations leading to Dunaway's hypothesis.

115. Werschkul, D. F.; McMahon, E.; Leitschuh, M. Some effects of human activities on the great blue heron in Oregon. Wilson Bulletin. 88(4): 660-662; 1976.

The mean size of great blue heron rookeries was greater in undisturbed areas than in areas within 0.3 mi from logging operations. Nest density and nest occupancy were significantly less in disturbed heronries than in undisturbed ones. The average distance from the nearest point of disturbance was greater for active than

inactive nests. A shift in nesting activity away from the point of disturbance was observed in heronries near logging operations, but not in undisturbed heronries.

116. White, C. M.; Thurow, T.; Sullivan, J. F. Effects of controlled disturbance on ferruginous hawks as may occur during geothermal energy development. Geothermal Resources Council, Transactions. 3: 777-780; 1979.

Disturbance treatments consisted of frequent walking and driving to the nest and placing noisemakers near the nest. Hawk responses to disturbance were highly variable. Several nests were deserted and not reoccupied during the following year. Little nest failure was evident, but treatment nests fledged significantly fewer young than control nests. The author suggests a 1 mi buffer zone be established around each nest to minimize adverse impacts.

117. Willard, D. E. The impact of transmission lines on birds. In: Avery, M. L., ed. Impacts of transmission lines on birds in flight: proceedings of a workshop, Oak Ridge Associated Universities; 1978 January 31-February 2; Oak Ridge, TN. FWS/OBS 78/48. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services; 1978: 3-7.

Collisions with transmission lines have been reported for approximately 280 species of birds. Collisions involving swans, pelicans, cranes, and eagles have been reported in greater numbers than their populations would suggest. Many kills apparently occur when large numbers of birds are surprised in conditions of poor visibility. Disturbance may be an important factor. Some species are more sensitive at specific places and times, such as during the breeding season. Collisions represent a small proportion of deaths nationwide, but may be significant locally and/or for species with small populations.

118. Witmer, G. W. Roosevelt elk habitat use in the Oregon coast range. Corvallis, OR: Oregon State University; 1982. 104 p. Ph.D. dissertation.

Habitat use data indicated that use of road areas by Roosevelt elk was inversely related to vehicular disturbance. Elk avoided roads, especially paved through roads. Cows exhibited the greatest avoidance response during calving and rut. Security needs appeared more important than weather in precluding movement of elk far into openings. Researchers have calculated that 23 to 50 percent of a section of land (640 acres), when bisected by a paved through road, would be forgone to elk. The author recommends closure of secondary roads.

119. Woodard, T. N.; Gutierrez, R. J.; Rutherford, W. H. Bighorn lamb production, survival, and mortality in southcentral Colorado. Journal of Wildlife Management. 38(4): 771-774; 1974.

Research determined that the bighorn sheep population under study was declining or stabilizing at a low number. Ewe-lamb ratios declined significantly between June and September. The approximate cause of lamb mortality and the consequent low population density was believed to be a pneumonia complex. The sheep were lambing at a high elevation where stress from early bad weather may have increased the lambs' susceptibility to disease. The ultimate cause of high lamb mortality was unknown but may have been related to a loss of historical winter range due to livestock operations. It has been shown that acquisition of critical winter range can increase lamb survival.

120. Wright, J. M.; Fancy, S. G. The response of birds and caribou to the 1980 drilling operation at the Point Thomson No. 4 well. 1980. Final report prepared for Exxon Co., U.S.A. by L.G.L. Ecological Research Associates, Inc. [place of publication unknown], 62 p.

Data on the responses of birds to an exploratory drilling operation on the Arctic coastal plain showed that bird species composition, community structure, abundance, and nest density were similar at the drilling and control sites. No consistent pattern of increased nesting failure was observed in areas close to disturbance. Elimination of 5 acres of one type of habitat did not eliminate nesting birds, but caused a change in species composition. Helicopters flushed many birds from nests, but did not cause a reduction in nest density. Oldsquaw ducks at the control site appeared more sensitive to disturbance than those at the drilling site. This may be evidence of habituation by the latter to constant nearby noise and activity or may have been related to the small size of the control group and/or the limited area of protected water available to them. Caribou were observed (1) in significantly fewer numbers, (2) for shorter periods of time, (3) moving at a faster rate, and (4) traveling more and feeding and resting less in the drilling area than in the control area. Caribou tended to avoid the area within 3,900 ft of the drilling site. Approach by personnel each time caribou entered the drilling site was considered the most important disturbance. Based on the results of other research, the authors believe that caribou will not continue to avoid the area when the sources of disturbance are removed (after one season).

121. Johnson, B. K.; Lockman, D. Response of elk during calving to oil/gas drilling activity in Snider Basin, Wyoming. Pittman-Robertson Job Completion Report #W27R. 1980. On file at: Wyoming Game and Fish Department, Big Piney, WY. 14 p.

Preliminary data show elk responded to drilling-associated activity by avoiding roads and the drill site. Elk use of the basin was greater after than during drilling operations. The animals moved away from the drill site and did not appear to adjust to its presence. Elk cows moved their calves away from access roads at an earlier age during the summer when drilling occurred. Elk exhibited the strongest response to activity on roads. Few conclusive data are available on the effect of the drilling rig on elk distribution and use of meadows.

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Bromley, Marianne. Wildlife management implications of petroleum exploration and development in wildland environments. General Technical Report INT-191. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 42 p.

This report describes: (1) petroleum exploration, development, and production; (2) potential environmental disruptions; (3) effects of disruptions on wildlife behavior, habitat, and populations; and (4) strategies for minimizing and mitigating adverse effects. The section on impacts includes a detailed outline/index referring to an annotated bibliography. Major wildlife groups discussed are ungulates, carnivores, waterfowl, raptors, songbirds, shorebirds, and furbearers. Fish and other aquatic organisms are not covered.

KEYWORDS: petroleum development, wildlife, impacts, disruption, mitigation, bibliography

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